



**US Army Corps  
of Engineers**  
Waterways Experiment  
Station

Technical Report EL-95-18  
May 1995

*Environmental Impact Research Program*

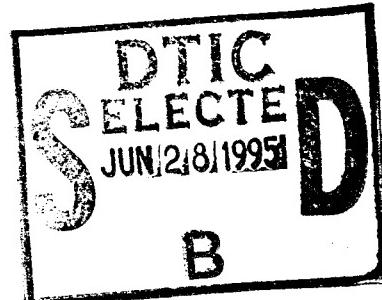
# **Physical Habitat Analysis Using the Riverine Community Habitat Assessment and Restoration Concept (RCHARC): Missouri River Case History**

by *John M. Nestler, L.Toni Schneider, WES*  
*Douglas C. Latka, Missouri River Division*  
*Peter N. Johnson, ASCL Corporation*

Approved For Public Release; Distribution Is Unlimited

19950627 056

DTIC QUALITY INSPECTED 5



The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.



PRINTED ON RECYCLED PAPER

# **Physical Habitat Analysis Using the Riverine Community Habitat Assessment and Restoration Concept (RCHARC): Missouri River Case History**

by John M. Nestler, L.Toni Schneider

U.S. Army Corps of Engineers  
Waterways Experiment Station  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199

Douglas C. Latka

U.S. Army Engineer Division, Missouri River  
12565 West Center Road  
Omaha, NE 68101-0103

Peter N. Johnson

ASCI Corporation, Inc.  
Trotter Shoals Laboratory  
Highway 72 West, P.O. Box 533  
Calhoun Falls, SC 29628

## **Final Report**

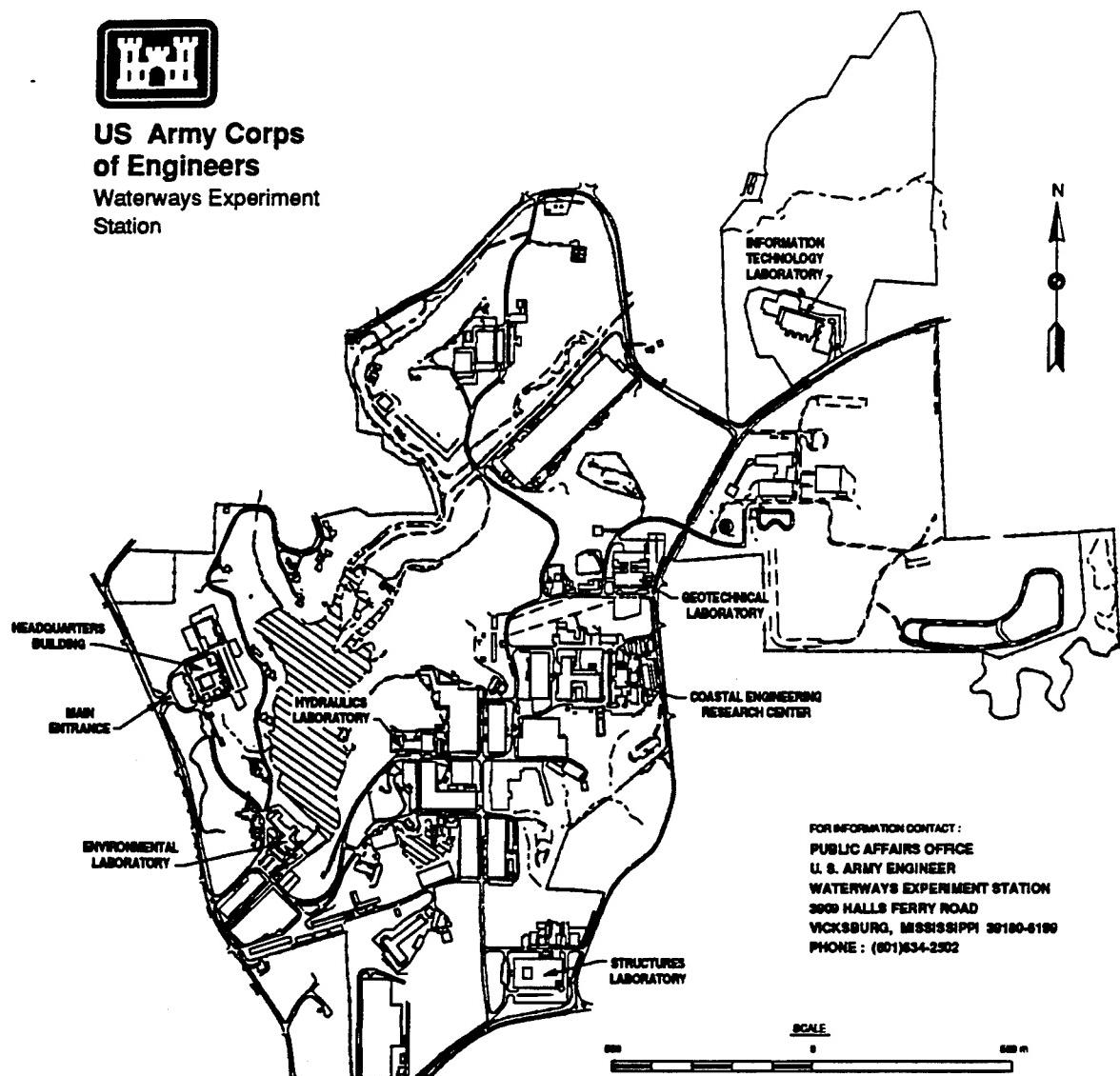
Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers  
Washington, DC 20314-1000

and U.S. Army Engineer Division, Missouri River  
Omaha, NE 68101-0103



**US Army Corps  
of Engineers**  
Waterways Experiment  
Station



**Waterways Experiment Station Cataloging-in-Publication Data**

Physical habitat analysis using the Riverine Community Habitat Assessment and Restoration Concept (RCHARC) : Missouri River case history / by John M. Nestler ... [et al.] ; prepared for U.S. Army Corps of Engineers and U.S. Army Engineer Division, Missouri River.

106 p. : ill. ; 28 cm. — (Technical report ; EL-95-18)

Includes bibliographical references.

1. Tailwater ecology — Evaluation — Mathematical models. 2. Fishes — Missouri River — Habitat — Evaluation. 3. Aquatic habitats — Missouri River. I. Nestler, John M. II. United States. Army. Corps of Engineers. Missouri River Division. III. U.S. Army Engineer Waterways Experiment Station. IV. Environmental Laboratory (U.S. Army Engineer Waterways Experiment Station) V. Environmental Impact Research Program (U.S.) VI. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; EL-95-18.

TA7 W34 no.EL-95-18

# Contents

---

Preface .....	vi
Conversion Factors, Non-SI to SI Units of Measurement .....	viii
1—Introduction .....	1
Background .....	1
Problem .....	2
Objective .....	2
Model Strategy .....	2
Approach .....	4
2—Riverine Community Habitat Assessment and Restoration Concept .....	6
3—Implementing the RCHARC .....	11
Steps in Applying the RCHARC .....	11
Channel descriptions .....	11
Hydrologic summaries .....	11
Stage-discharge information .....	11
Depth and velocity distributions .....	11
Relative impacts of each project alternative .....	12
Correct for top width .....	12
Trends and patterns in the results .....	12
Channel Descriptions .....	12
Hydrologic Summaries .....	15
Hydraulic Information .....	16
Lateral flow pattern descriptions .....	16
Depth and velocity distributions .....	19
Univariate Analysis .....	19
Depth-velocity distribution .....	19
Relative impacts of each project alternative .....	21
Correction for top width .....	26
Bivariate Analysis .....	30
Depth-velocity distributions .....	30
Relative impacts of each project alternative .....	31
4—Trends and Patterns in the Results .....	33
5—Sources of Error and Uncertainty .....	46
6—Discussion .....	48

7—Conclusions and Recommendations .....	52
References .....	55
Tables 1-3	
Appendix A: Top Widths and Correlation Coefficients of Gavins Point Tailwater .....	A1
Appendix B: Gavins Point Canberra Coefficients .....	B1
SF 298	

## **List of Figures**

---

Figure 1. Conceptual relationship between a depth or velocity distribution and habitat requirements of a hypothetical group of species represented by an ordinated set of habitat suitability curves .....	8
Figure 2. Comparison of a single population or guild analysis with the RCHARC approach .....	9
Figure 3. Simplified overview of steps involved in applying the RCHARC .....	13
Figure 4. Depiction of method used to correct the CSRS velocity distributions .....	21
Figure 5. Comparison of the velocity distributions made at a 6,000-cfs discharge .....	22
Figure 6. Comparison of velocity distributions made at a 50,000-cfs discharge .....	23
Figure 7. Comparison of the depth and velocity frequencies between the CSRS at a discharge of 18,000 cfs (historical) and project channel conditions at a discharge of 28,000 cfs (operational) for the wide channel category .....	24
Figure 8. Comparison of the depth and velocity frequencies between the CSRS at a discharge of 43,000 cfs, project channel at a discharge of 40,000 cfs, and special holdout run .....	25
Figure 9. Cumulative frequency distribution developed from the depth and velocity information from one cross section for each of three discharges .....	27
Figure 10. CSRS frequency distribution .....	28
Figure 11. Sum weighted correlation coefficients .....	29

Figure 12. Comparison of a cross section in the divided category collected prior to impoundment with project cross section collected at Gavins Point, RM 783.6, but after many years of regulation .....	34
Figure 13. Comparison of a cross section (RM 786.8) in the narrow category collected prior to impoundment with that after many years of regulation .....	35
Figure 14. Comparison of a cross section (RM 797.5) in the transitional category collected prior to impoundment with that after many years of regulation .....	36
Figure 15. Comparison of a cross section (RM 778.9) in the wide category collected prior to impoundment with that after many years of regulation .....	37
Figure 16. Monthly value functions (constructed from correlation coefficients) for the wide channel category for depth .....	39
Figure 17. Monthly value functions (constructed from correlation coefficients) for the wide channel category for velocity .....	40
Figure 18. Monthly value functions (constructed from correlation coefficients) for the wide channel category for depth corrected for top width .....	41
Figure 19. Monthly value functions (constructed from correlation coefficients) for the wide channel category for velocity corrected for top width .....	42
Figure 20. Summary results for an application of the RCHARC to the Gavins Point tailwater .....	45
Figure 21. Bivariate contour plots for narrow channel .....	49
Figure 22. Preproject contour plots and difference in frequency plots for wide and transitional channels .....	50

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/ _____	
Availability Codes	
Dist	Avail and/or Special

# Preface

---

This study was conducted by the Environmental Laboratory (EL) of the U.S. Army Engineer Waterways Experiment Station (WES) under Work Unit 32698 entitled "Assessing Benefit of Channel Modifications for Aquatic Habitat in Tailwaters and Local Flood Control Channels" of the Environmental Impact Research Program (EIRP) sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE). Technical monitors were Dr. John Bushman and Mr. Frederick B. Juhle, HQUSACE. Dr. Roger T. Saucier, EL, was EIRP Program Manager. The study was co-funded by the U.S. Army Engineer Division, Missouri River (MRD), as part of the Missouri River Water Control Manual Review.

The report was prepared by Dr. John M. Nestler and Ms. L. Toni Schneider of the Water Quality and Contaminant Modeling Branch (WQCMB), Environmental Processes and Effects Division (EPED), EL, Mr. Doug Latka of MRD, and Mr. Peter N. Johnson, ASci Corporation, at Trotter Shoals Research Facility, Calhoun Falls, SC. Dr. Nestler, Ms. Schneider, and Mr. Johnson prepared the software used in the analysis. All four authors performed the analysis. Mr. Latka obtained archived cross-section data and supervised the field collection of new cross-section information. Mr. Latka also provided information on channel processes acting to change the preproject cross sections to their present shapes and helped develop the concepts on which the Riverine Community Habitat Assessment and Restoration Concept is based. The hydraulic routing necessary to obtain the stage-discharge relationships used in the habitat analysis was performed by Mr. Brad Hall of the WES Hydraulics Laboratory. Mr. Hall also provided many helpful suggestions and recommendations during the course of the study.

Numerous individuals of the U.S. Army Engineer District, Omaha, and the MRD provided information that was integrated and summarized in this report. Members of the Environmental Subcommittee, who provided review comments or otherwise shared their knowledge, are gratefully acknowledged, in particular, Mr. David Carlson of the U.S. Fish and Wildlife Service, Grand Island, NE, and Mr. Larry Hesse of the Nebraska Game and Parks Commission, Norfolk, NE.

The study was prepared under the direct supervision of Dr. Mark S. Dortch, Chief, WQCMB, and under the general supervision of Mr. Donald L. Robey,

Chief, EPED, and Dr. John W. Keeley, Director, EL. Technical Review was provided by Ms. Dottie Hamlin-Tillman and Mr. Tom Cole, both of WQCMB. Messrs. Terry Gerald and Daniel Thompson of the WQCMB generated some of the figures used in the text.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce Howard, EN.

This report should be cited as follows:

Nestler, J. M., Schneider, L. T., Latka, D., and Johnson, P. N. (1995). "Physical habitat analysis using the Riverine Community Habitat Assessment and Restoration Assessment and Restoration Concept (RCHARC): Missouri River case history," Technical Report EL-95-18, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

*The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.*

# **Conversion Factors, Non-SI to SI Units of Measurement**

---

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers

# 1 Introduction

---

## Background

The U.S. Army Corps of Engineers (CE) controls, maintains, and conserves water resources to provide for flood control, navigation, irrigation, power generation, recreation, water quality, water supply, fish and wildlife protection and enhancement, and other authorized project purposes by regulating releases from dams. The degree to which preimpoundment flows are regulated depends upon project purposes. Alteration of preimpoundment flows ranges from relatively long-term seasonal changes required to support navigation or to provide for downstream flood protection to extremely short-term changes required for peaking hydropower generation.

Increased economic development in river basins, plus changing demographic, social, and land use patterns, is placing increased demands on the natural resources in river systems. Operation of dams impacts several natural resource categories including inpool reservoir fish resources, wetlands, wildlife, and downstream fish resources. Efforts by the CE to continue fostering economic development in river basins, while simultaneously protecting environmental quality, require the availability of predictive tools that can be used to balance the developmental and environmental needs of the region.

This report documents the approaches and underlying rationale used to comparatively assess the effects of physical habitat changes resulting from alternative reservoir operations on the native warmwater riverine fish community in the tailwaters of the main stem dams on the Missouri River. The main stem Missouri River reservoir system extends from Montana to Nebraska and includes the following reservoir projects: Fort Peck Dam (River Mile (RM) 1771.5), Garrison Dam (RM 1389.9), Oahe Dam (RM 1072.3), Big Bend Dam (RM 987.4), Fort Randall Dam (RM 880.0), and Gavins Point Dam (RM 811.1). However, results of the analysis are presented for the tailwater of Gavins Point Dam only because it was the most thoroughly studied and documented tailwater. Analysis of the other reservoirs on the main stem Missouri River having a downstream tailwater (instead of releasing into the headwaters of a downstream reservoir) can be found in Nestler, Schneider, and Hall (1993).

## **Problem**

Like many CE Districts and Divisions, the Missouri River Division (MRD) lacked systematic assessment tools necessary to analyze the effects of reservoir operation on physical habitat for native riverine fishes occurring in river reaches affected by reservoir operation. The lack of assessment tools prevented MRD from developing and documenting operational plans that optimize economic and natural resource categories in the main stem Missouri River. Assessment tools are required to predict and manage the environmental effects of reservoir operation to facilitate optimal use of this valuable resource. For example, a major water diversion may potentially impact fish in the system by altering flow regimes and water quality. Conversely, implementation of measures beyond those required to maintain and protect environmental quality of the system may preclude drawing benefits from other uses of water in the main stem system.

## **Objective**

The objective of this study was to develop a method that could be used to develop simple relationships between flow and habitat values allowing CE engineers and scientists to predict the tailwater habitat value downstream of reservoirs for different operational alternatives or channel configurations. The method was specifically designed to describe the effects of reservoir operation on tailwater fish habitat in a context suitable for reservoir-specific or basin-wide trade-off analysis. The method developed, the Riverine Community Habitat Assessment and Restoration Concept (RCHARC), is applied to the Gavins Point Dam tailwater as a case history that can be emulated for analysis of other reservoirs that release steady or gradually varied flows. Modifications to the RCHARC to allow assessment of peaking releases associated with hydropower operation can be found in Nestler, Schneider, and Hall (1993).

## **Model Strategy**

Analyzing environmental effects requires long-term time series estimates of the releases from the dam associated with each operational alternative. Usually the discharge estimates are obtained from a reservoir operation or basin hydrology model. Each alternative operation is represented as a set of rules that determines the operation of the dam as a function of reservoir stages or downstream flow requirements. The set of rules is applied to a hydrologic time series of inflows into the reservoir or reservoir system to determine the pattern of releases associated with each alternative. The summary environmental effects of each alternative are determined by integrating the environmental effects of each release at a particular time-step (usually 1 month) over the hydroperiod.

For this application of the RCHARC, MRD used the Long-Range Study (LRS) model to predict monthly reservoir stages and monthly reservoir discharges associated with each operational alternative (U.S. Army Engineer Division, Missouri River, 1992). The operating rules for each alternative were each run separately by the LRS model using the 93-year hydrological record available for the Missouri River. The LRS model generated a unique set of stages and discharges characteristic of each alternative that were the basis of the habitat analysis.

Use of a hydrologic model to generate stage and discharge information for each reservoir ordinarily limits the data available to perform the habitat analysis. The only data available to evaluate the alternatives are the unique monthly stages and discharges available for each alternative and data that are associated with the 93-year hydrological record. Time series of measured meteorological and water quality data are usually not as complete as the time series of stages and discharges predicted by the hydrology models. Consequently, the approach used to model tailwater habitat was restricted to those variables that were either predicted by the LRS model or whose trends could be derived from historical data linked to the 93-year hydrologic record.

For this application of the RCHARC, the software estimating the habitat impact of each alternative was coded as a separate module that was linked to the LRS model. The LRS model was run once for each alternative over the 93-year hydroperiod, and the output was passed to the module determining the monthly reservoir-specific tailwater habitat values for each flow alternative. Other resource categories can be assessed in a conceptually parallel method; i.e., each resource category is assessed by a separate module that is fed information from a common reservoir operation or basin hydrology model.

It is often necessary or useful that the results of a habitat analysis done as part of a trade-off assessment be expressed as a "value function;" i.e., each different average discharge has an associated habitat value ranging from 0.0 to 1.0 with 0.0 representing minimum value and 1.0 representing maximum value. Expressing the relationships between flow and different resource categories as value functions allows direct comparison of seemingly disparate resource categories such as recreation, warmwater fish habitat, or flood control benefits that are assessed using different units of measurements.

The habitat assessment of the Gavins Point tailwater using the RCHARC has the following steps:

- a. The LRS model predicts monthly flow estimates for each alternative over the 93-year period of record.
- b. Separate value functions are formulated for each month.
- c. Each monthly flow predicted by the LRS model is replaced by an associated habitat value.

- d. The effect of each alternative is obtained by summing (or integrating in some other way, e.g., using annual habitat minimums in cases where the annual flow pattern differs substantially from the comparison standard) the resulting habitat values over the 93-year period of record.
- e. The alternatives are evaluated against each other or against a standard to rank the alternatives and thus provide the rationale for selecting optimal operational plans as part of a trade-off analysis.

Assessing the effects of reservoir operation can be complicated by the choice of the “no-action” alternative. For this application of the RCHARC, MRD determined that the no-action alternative is defined by the present system of rules currently used to operate the main stem Missouri River dams. Ordinarily, the no-action alternative serves as an implicit standard against which other alternatives can be evaluated. In this case, the no-action alternative is itself an operational alternative (and not an unregulated condition) whose habitat value has not been quantified. The no-action alternative was treated as one of the operational alternatives, and its habitat impact was evaluated by comparing its depth/velocity distributions to the “comparison standard.” The relative impacts of alternative operations were then evaluated relative to the score of the no-action alternative. Thus, the habitat impact of each alternative, including the no-action alternative, was first quantified against the “standard of comparison.” The habitat value of each alternative flow, including the no-action alternative, was then ranked using the standard of comparison as the impact gauge. The habitat impacts of the project alternatives were evaluated against the habitat value of the no-action alternative to complete the analysis.

## **Approach**

The “value function” assessment framework developed by the MRD requires that a systematic procedure be developed to determine the habitat value of each monthly flow for the tailwater. Various methods are available to relate flow to fish habitat value (Reiser, Wesche, and Estes 1989). The most commonly applied methodology, the Physical Habitat Simulation System (PHABSIM) of the Instream Flow Incremental Methodology (IFIM), developed by the U.S. Fish and Wildlife Service (USFWS) (Milhous, Updike, and Schneider 1989), has received considerable criticism for applications on large, warmwater river systems (Bain and Boltz 1989; Nestler 1993). Even if the IFIM were considered defensible for this application, the short time frame available for this study prevents its application for the numerous warmwater fishes occurring in the Missouri River system.

Suitability curves relate the habitat value of different depths and velocities to species life stages or guilds (Bovee 1986). Major alterations in channel morphology and flow regime make development of defensible suitability curves problematic. As Tyus (1992) points out, it is difficult to develop suitability curves for impacted species in highly modified systems because the

system is deficient in one or more critical habitat components or else the impacted species would not be rare. It is difficult or impossible to develop suitability curves for habitat features that are rare or missing. Therefore, it is unlikely that habitat suitability curves developed from a highly impacted system like the Missouri River will capture all necessary habitat features required by the target species.

Additionally, developing a single value that relates the value of a particular flow alternative to the entire warmwater fish community would be nearly impossible using suitability curves as the basis of the analysis. The approximately 60 species and four life stages per species require the flow requirements of nearly 250 species' life stages be determined, summarized, and integrated. Creation of defensible suitability curves for even one species can be difficult and time-consuming (Bovee 1986). Formulating habitat suitability information on even a few species in large rivers can be a particularly expensive and protracted activity because of the difficulty in sampling at the large temporal and spatial scales characteristic of large river systems.

While use of suitability information to define the habitat requirements of large warmwater fishes does not seem to be technically desirable or logically feasible, sufficient literature is available that suggests that fishes respond to depth and velocity patterns including fishes in large warmwater rivers (Bain, Reed, and Scheidegger 1991). Bain, Reed, and Scheidegger (1991) point out that the distribution of warmwater fishes in the Cahaba River system of Alabama, a large, southeastern, warmwater river system supporting fish species that also occur in the Missouri River, can be largely explained using broad depth and velocity categories. The work of Bain, Reed, and Scheidegger suggests that broad depth and velocity information should be included in a habitat analysis. However, because of the limitations associated with the use of habitat suitability information, depth/velocity information should be incorporated in a manner that does not use species life stage or guild habitat suitability curves.

A large warmwater river system such as the Cahaba River, Alabama, can have nearly 100 species, each of which can have several life stages. Attempting to create the necessary suitability curves, determine the flow-habitat relationships based on each curve, integrating the population level information to make community-level statements, and then distilling this information to facilitate wise decision making is a daunting task. A more feasible approach is to find a reach of river that contains a healthy community. The physical habitat patterns over an annual cycle of this river reach can then be used as a standard to which the habitat conditions in an impacted system can be compared.

## **2 Riverine Community Habitat Assessment and Restoration Concept**

---

Based on considerations discussed in the previous section, RCHARC, a new approach for relating the effects of flow alterations and alternative channel designs on aquatic biota, was developed. This system combines conceptual elements of the Index of Biotic Integrity (IBI) (Karr et al. 1986) and the PHABSIM system. Like the IBI, the RCHARC requires use of a river system as the basis of comparison, that is, a "comparison standard" for the analysis against which the various project alternatives can be evaluated. The comparison standard river system (CSRS) is considered to represent the ideal habitat conditions, both in terms of channel configuration and seasonally varying flow characteristics, for the aquatic community in the project river system. The CSRS can be selected based on professional consensus, physical similarity to the project system, or similarity of the aquatic community in the standard system to what is desired in the project system. The CSRS can be a nearby river system, reaches of the river further upstream or downstream of the project and not impacted by the project, or the project river reach but evaluated in a "without-project" condition.

For this study, the CSRS was considered to be the preproject Missouri River channel under preproject flow conditions. This choice was based on several considerations. First, channel modification resulting from flow regulation and disruption of downstream sediment transport has been documented on numerous occasions (e.g., U.S. Army Engineer District, Omaha, 1989). There seems to be concomitant decline in those species that comprise the native warmwater fish community of this river (Gardner and Stewart 1987; Pfleiger and Grace 1987; Schmulbach 1974; and Hesse et al. 1989). These same authors have speculated that the decline in these species is related to the impacts of regulation on a variety of factors, including alteration in downstream physical habitat.

This study assumes that a return to preproject habitat conditions for both flow and channel characteristics should provide optimum physical habitat for the warmwater fish community of the Missouri River, all other factors being equal. Many ecological processes are influenced by depth and velocity

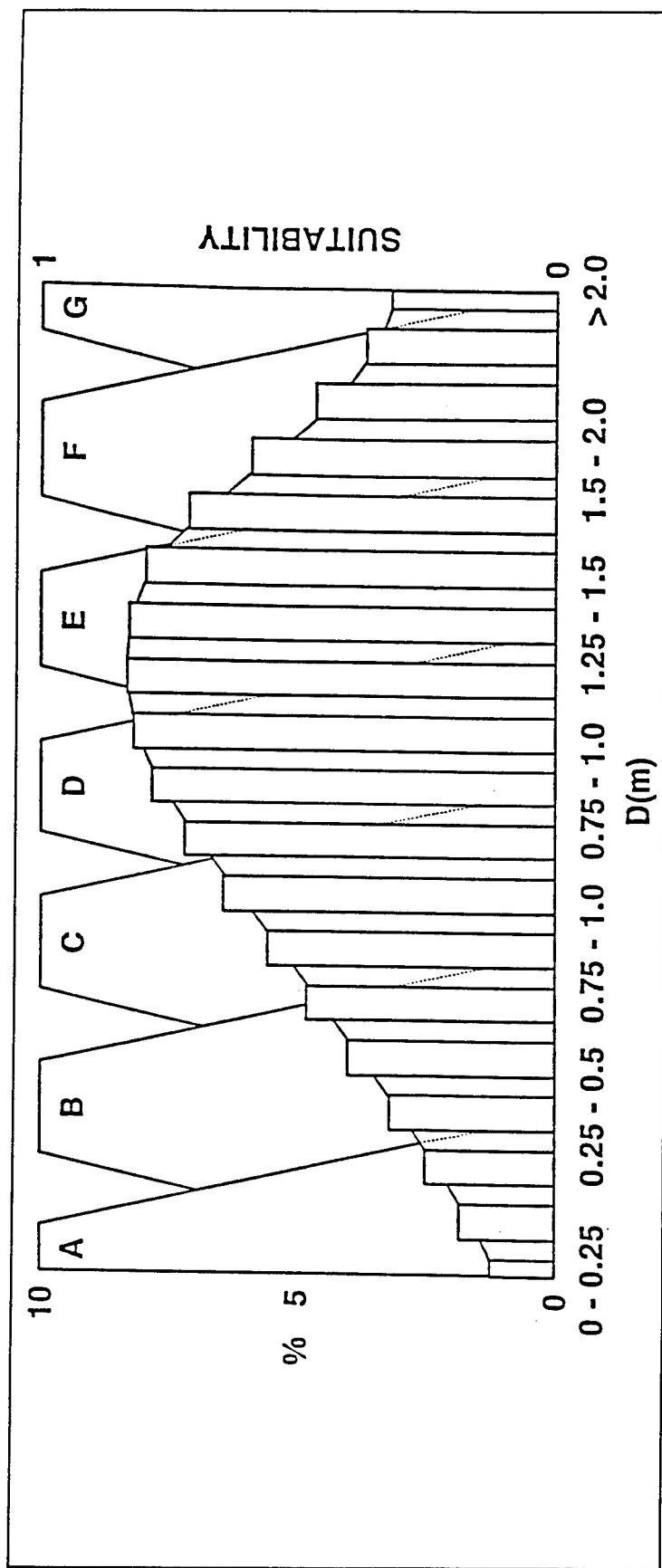
conditions in the channel, such as organic matter transport, substrate composition, and bed form, so that a return to preproject flow conditions should also tend to return these flow-associated factors closer to their preproject conditions. In the context of an RCHARC assessment, a project alternative that provides depth, velocity, and top width conditions closer to the CSRS, in this case the preproject Missouri River, will rank higher than a project alternative that provides less similar conditions.

Although the RCHARC does not directly assess impacts on species using life stage-specific suitability curves, this information is implicit in the methodology. For a given flow, a distribution of depth and velocity is associated with that flow (Figure 1, left ordinate). These distributions represent the habitat template upon which the community is structured. As Bain, Reed, and Scheidegger (1991) have pointed out, some species will ordinate along shallow portions of the depth distribution and others will ordinate out on deeper portions of the depth distribution. Thus, the composition of the fish community will be determined by the distribution of depth/velocity, all other factors being equal. Changes in the frequency distribution of depth and velocity will result in associated changes in the warmwater fish community. A shift in the frequency distribution of depth that reduces the amount of shallow water will favor species that require deeper water (Figure 1).

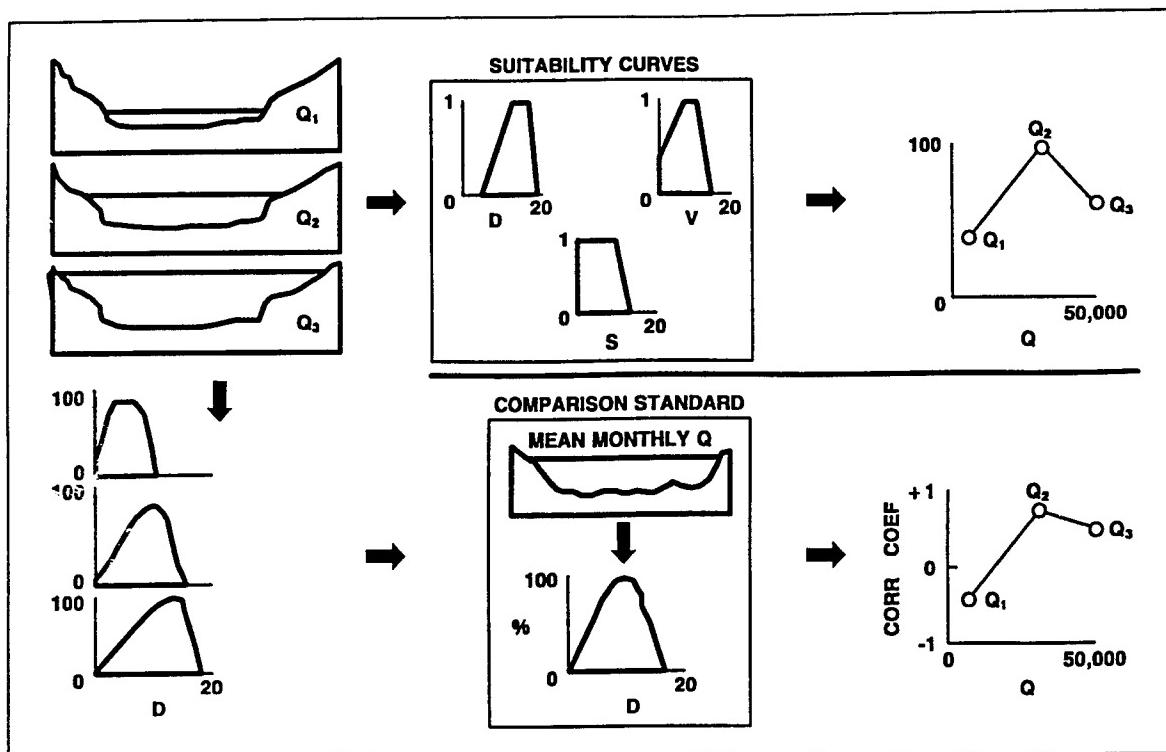
Competition and predation are included indirectly in RCHARC since the physical habitat of the standard system also provides the template upon which interspecies interactions such as competition and predation are structured. Thus, duplication of the physical structure of the standard system in the project system will also provide a template conducive to the duplication of species interactions.

The RCHARC summarizes physical habitat in rivers fundamentally differently from the methods employed in the PHABSIM system. Normally, instream flow studies using a habitat-based approach (the IFIM representing the most common approach) use point-by-point measures or predictions of depth and velocity in cells of cross sections under different discharges and relate each point to its suitability to a particular target life stage. The suitability curve in turn parallels the idea of simulating and evaluating habitat on a point-by-point basis. That is, each point is evaluated relative to a scale of 0 to 1 without consideration of other points (Figure 2). However, biologists have often observed that the habitat requirements for many aquatic species are based on more than simple point-by-point evaluations. For example, a predatory fish may select deeper, slower water as a velocity shelter, but the slower water will often be near faster water that will transport drift or other food entrained in the water (Hughes and Dill 1990). A more complete analysis may indicate that much of the food eaten by the predatory fish may be produced in a specific part of the river such as a riffle.

Depiction of the habitat requirements of stream fishes in a methodology that focuses on point-by-point analyses is unrealistic because there is no explicit mechanism to include habitat diversity in the assessment.



**Figure 1.** Conceptual relationship between a depth or velocity distribution and habitat requirements of a hypothetical group of species represented by an ordinatated set of habitat suitability curves. The left ordinate represents the percent distribution of each depth or velocity increment. The right ordinate represents the habitat value from 0.0 to 1.0 for each depth or velocity. The relative value of the habitat for each species can be determined by how much of the frequency distribution falls within its suitability curve, or restated, the composition of this hypothetical group of species is at least partially determined by the distribution of depth and velocity



**Figure 2.** Comparison of a single population or guild analysis with the RCHARC approach. Both approaches begin with channel cross-section information (cross section at three discharges,  $Q_1$ ,  $Q_2$ , and  $Q_3$ ) with cell-specific depth and velocity information available in each cell at the different discharges. In the usual habitat-based approach, the cell-by-cell depths and velocities at each discharge are separately evaluated against suitability curve information. The habitat value of a particular cross section at a particular discharge is obtained by summing the habitat values of its component cells to generate the plot in the upper right. The plot relates the habitat value of the transect at each discharge to the habitat requirements of the biological target. However, expanding this approach to a community or ecosystem level can be difficult and cumbersome. In the RCHARC approach, the cell-by-cell depth and velocity information for each discharge is summarized with a frequency distribution. The three resulting frequency distributions are then compared to the frequency distribution of the habitat standard to determine how the alternatives rank to the standard (plot in lower right)

Point-by-point analysis may show that a stream with relatively uniform hydraulic conditions (i.e., a ditch) provides optimum habitat for a particular life-stage because all of the depth and velocity conditions fall within the maximum habitat value of the suitability curve. Conversely, a stream containing highly diverse hydraulic conditions may be evaluated as poor habitat. Physical habitat patterns in streams can be described more realistically in a methodology based on cumulative frequencies of hydraulic conditions. Depiction of a stream reach in terms of frequency distributions of depth and velocity is more likely to capture the stream heterogeneity having value to aquatic biota both at the population and community levels than a method that focuses on point-by-point analyses. If a cell is the level of analysis for a species, it seems

reasonable that the appropriate level of analysis for the community is a frequency analysis of cell conditions in a reach.

The holistic perspective of the RCHARC provides a better framework to evaluate the ecosystem-level differences between the CSRS and the project streams by better describing the fluvial-geomorphic factors that affect fish habitat (Hill, Platts, and Beschta 1991). The system-level perspective is applied later in this report using the Gavins Point tailwater as an example to better determine how the project alternatives for the Missouri River differ from the CSRS. The stream worker can use this approach to assess broad differences in hydraulic patterns between the CSRS and the project alternatives and to better understand how patterns of physical habitat will be affected by different alternatives. It is also possible to gain a qualitative understanding of other aquatic processes such as the potential for bed form changes or potential for organic matter transport.

Rather than attempting to unweave the complex tapestry of habitat requirements for each species, the RCHARC compares the underlying patterns of depths and velocities in the two systems and uses the results as the basis of the community-level impact analysis. The degree of impact is approximated by the degree to which the physical habitat changes between the target and standard systems. Once the RCHARC analysis is complete, it can provide information useful at a population level of analysis by identifying major differences in habitat between the standard and target systems. These differences in physical habitat patterns can be evaluated, qualitatively or quantitatively, to determine habitat features whose absence may account for the decline of endemic, rare, or endangered species.

# **3 Implementing the RCHARC**

---

## **Steps in Applying the RCHARC**

The RCHARC is composed of a number of discrete steps summarized in the following paragraphs. Application and interpretation of the RCHARC analysis to the Gavins Point tailwater are discussed in the succeeding sections.

### **Channel descriptions**

The CSRS channel and project alternative channels must each be identified and described using fine-resolution cross-section information. Sufficient information for the CSRS and project alternatives must be available to allow description of discharge-specific depth and velocity distributions.

### **Hydrologic summaries**

The dominant hydrologic patterns associated with the CSRS and each of the project alternatives must be summarized using summary statistics (e.g., median flows or flow extremes) and time-steps adequate to describe the hydrologic behavior of all systems.

### **Stage-discharge information**

Stage-discharge information for the CSRS and project alternative cross sections must be obtained from hydraulic models, gauge information, or field measurements. The stage-discharge information is combined with channel cross-section information to generate discharge-specific depth and velocity distributions for the CSRS and the project alternative channels.

### **Depth and velocity distributions**

The hydraulic information is summarized as percent distributions of depth and velocity for both the CSRS and project alternatives. The percent

distributions for depth and velocity (treated as separate variables or combined in a bivariate depiction) for each of the project alternatives are evaluated for their similarity to the CSRS (Figure 3) at appropriate time-steps (e.g., monthly) using qualitative inspection, correlation analysis, similarity analysis, or other methods for determining degree of similarity.

### **Relative impacts of each project alternative**

The correlation coefficients for each project alternative are summed, month by month, over the period of the hydrologic record. The project alternative that provides depth and velocity conditions most nearly like the CSRS will have the largest sum, and the project alternative having the least similarity should have the smallest sum.

### **Correct for top width**

In some cases it may be possible for the top widths of the CSRS and project alternative channels to vary substantially even though the depth or velocity distributions are very similar. As an option, the correlation coefficients can be linearly adjusted by the degree to which project alternative channel top widths differ from the CSRS channel topwidths.

### **Trends and patterns in the results**

As with any methodology that distills complex systems into single number rankings, it is important to explore the significance of differences and similarities among project alternatives and between the project alternatives and the CSRS.

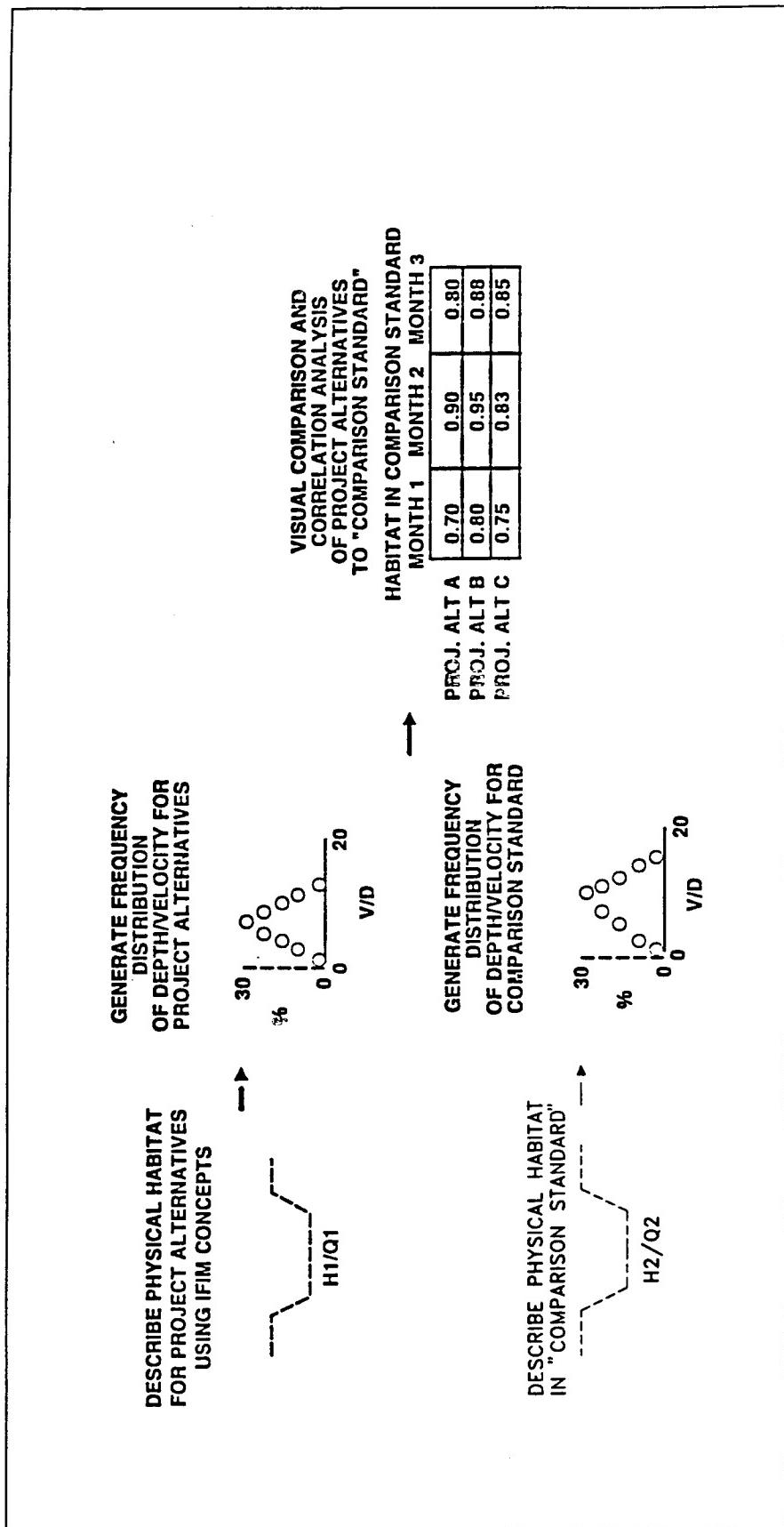
## **Channel Descriptions**

Physical habitat in the CSRS and the project alternatives must be described using channel cross-section data. Transect data must be of sufficient detail to allow adequate characterization of aquatic habitat—usually requiring at least 20 points in the channel and a vertical accuracy of 0.5 ft<sup>1</sup> for a system as large as the Missouri River. A sufficient number of transects must be identified and selected to characterize the habitat variability of a river reach. Usually, a minimum of four to eight transects is required.

MRD has collected and archived channel cross-section data for the Missouri River at approximately 5-year intervals beginning with cross

---

<sup>1</sup> A table of factors for converting non-SI units of measurement to SI units is presented on page viii.



**Figure 3.** Simplified overview of steps involved in applying the RCHARC. First, the CSRS channel is described and simple hydraulic characteristics are determined for appropriate stage-discharge pairs (single pair, H1/Q1, is used in this example, but most examples would have more pairs). The H1/Q1 pair in conjunction with other information is used to determine the distribution of depth  $D$  or velocity  $V$  in the channel. A similar process is followed to determine the depth or velocity distribution in the project alternative. The resulting distributions are compared using correlation analysis or a similarity statistic to determine how a project channel compares to a standard channel. This process would be repeated nine times to generate the table of correlation coefficients in the figure

sections collected prior to or immediately after closure of each of the dams and extending to the present. Each cross section is composed of approximately 100 points with a vertical accuracy of 0.1 to 0.2 ft. Available channel cross sections were evaluated by MRD. Between 6 and 10 cross sections for each tailwater were selected to represent major habitats in the river from the dam to the headwaters of the next downstream reservoir. Major habitats included backwaters, chutes, main channels, and sandbar areas. For each tailwater, channel cross sections included major habitat features in approximately the same proportion that they existed in the entire river reach. State and Federal biologists used aerial photographs, existing cross sections, and site visits to select transects for measurement. Preregulation transects were selected from historic data collected at the same locations or as close as possible to the transects selected for measurement.

Cross sections for Gavins Point were categorized by top width as narrow, wide, transitional, or divided. After selection of cross sections from MRD archives, each location was resurveyed under both a high- and low-flow condition using standard stream gauging methods to define the channel conditions for project alternatives. Results of the two surveys were used to prepare two velocity calibration data sets that would be used to calibrate the hydraulic models used to simulate lateral cross-section velocities. Two resurveys were used to get a better approximation of the channel shape associated with the two dominant flows. Median flow used to support navigation during the navigation season was approximately 30,000 cfs. Median flow during the non-navigation season was approximately 10,000 cfs.

Channel cross-section and velocity data for this predominantly sand bed river were also collected at a high flow and a low flow because the channel shape might change between the two flow extremes. This reduced the risk that a channel cross section obtained under high-flow conditions would not be representative of channel shape at lower discharges, particularly at the edges of the channel. However, comparison of the high- and low-flow cross sections at both flows at similar locations indicated only relatively minor changes in channel shape. The two velocity calibration data sets were collected near the two end points of the flow range representative of most of the operational alternatives, ensuring that any change in flow pattern would be captured by the two calibration data sets.

The complete channel data set available for RCHARC analysis consisted of river cross-section information collected at the same locations (or usually within several tenths of a mile) for Gavins Point tailwater prior to or near closure of the dam immediately upstream and again in 1989 or more recently. Detailed descriptions of the channel cross-section information available are described later in this section.

The Gavins Point cross sections were resurveyed 13-19 March and 10-19 July 1989 by a team composed of representatives of the Nebraska Game and Parks Commission, the U.S. Geological Survey (USGS), and U.S. Army Corps of Engineers. Flows ranged from 8,000 to 10,500 cfs during the March

data collection and were approximately 30,000 cfs during the July measurements. Eight transects in the reach were selected for data collection, each representing a different river type. Only six locations were surveyed during March because of bad weather and increased releases from Gavins Point for the start of the navigation season. In March, cross-section data were collected at RM 778.90, 780.92, 783.61, 786.73, 797.50, and 804.28. July cross sections were at 755.56, 778.90, 780.92, 783.61, 786.73, 793.60, 797.50, and 804.28. The preproject cross sections were collected from 1955 through 1959.

## Hydrologic Summaries

The description of the CSRS consists of both channel characteristics occurring over long-term discharge patterns. River discharges vary by location on the Missouri River because of tributary inflow. Monthly discharges for the period of record to characterize the CSRS were obtained from LRS model output using a run in which the storage of the reservoirs was "held out." Therefore, the output of the LRS model would simulate the hydrologic behavior of the Missouri River as though the dams had not been constructed. These "holdout runs" were used to generate preproject hydrological patterns.

Use of the LRS model allowed MRD to simulate the preproject hydrology of the Missouri River before data were consistently available for all present gauge locations; that is, the LRS model was able to synthesize gauge information at locations having incomplete records. Additionally, the LRS model could simulate the period of record after the project was constructed as though the dam did not exist. Use of existing gauge information to characterize the preproject Missouri River provided a hydrologic record limited to a duration as short as 24 years for one of the main stem Missouri River tailwaters. A 24-year record is inadequate to describe relatively long-term drought-flood cycles that characterize the Missouri River. The LRS model could provide a 93-year hydroperiod to more completely characterize the preproject hydrological conditions.

Variation in flows from year to year can have important influences on the distribution of aquatic organisms. Variation in flows may favor species that evolved in the unregulated river system under naturally occurring discharge and channel conditions at the expense of exotic or introduced species. Consequently, consideration of the median or mean flow only may not adequately relate the effects of the preproject hydrology on the integrity of the native warmwater fish community. Three categories of preproject flows were each considered to define a CSRS; low flow (75 percent exceedance), median flow (50 percent exceedance), and high flow (25 percent exceedance) conditions for the Gavins Point reach, as shown in the following tabulation:

Month	Median	High	Low
1	12.0	15.0	9.0
2	16.5	21.0	13.5
3	40.0	50.0	32.0
4	38.0	49.0	27.0
5	47.0	59.0	34.0
6	81.0	106.0	55.0
7	42.0	59.0	29.0
8	19.0	24.0	14.0
9	17.0	23.0	3.5
10	17.5	22.0	14.0
11	16.5	20.0	13.5
12	11.0	14.0	8.0

The annual monthly time series associated with each flow category for each year was derived from analysis of data generated by the LRS model and provided to the U.S. Army Engineer Waterways Experiment Station (WES) by MRD. An artificial "median flow year" was composed of the median flow from each month. For example, the median flow year for the Gavins Point tailwater was synthesized by obtaining the 50 percent exceedance flow for each month for the Yankton Gage (a gage in the tailwater of Gavins Point). A conceptually similar process was used to synthesize the low-flow and high-flow CSRS's for the Gavins Point tailwater. During application of the RCHARC to the 93-year period of hydrologic record, each water year under the "holdout" operation of the LRS was assigned to one of the three exceedance categories according to rules developed by the MRD.

## Hydraulic Information

### Lateral flow pattern descriptions

IFG-4, one of the hydraulic programs within the PHABSIM system, was used to develop the lateral flow (velocity) pattern at each transect using information from stage-discharge relationships, channel cross-section information, and two velocity calibration data sets. The hydraulic component of the PHABSIM system assumes that the shape of the channel does not change with streamflow over the range of flows being simulated. The results of the hydraulic calculations are water surface elevations and velocities. The water surface elevations are one-dimensional in that the same value is used for any point on a cross section. In contrast, the velocity varies from point to point across any cross section.

Several options within the IFG-4 program are available to generate cell depths and velocities for a given discharge. The IFG-4 program can employ several methods to synthesize cell-by-cell velocities if calibration velocities are unavailable. For this application, the hydraulic radius option was used to separate the total discharge at each transect into cells. This option results in deeper cells having greater water velocities. Alternatively, velocity measurements made in the field under steady flows at one or more discharges can be used for calibration. The measured velocities are used to solve Manning's equation for Manning's n for each cell. The calculated cell-specific n values are then used to generate estimates of velocities for each cell over a range of simulated discharges. After estimating a lateral velocity pattern based on the calculated Manning's n, the IFG-4 program then checks the calculated water surface elevation against the given water surface elevation provided from another source (described in the stage-discharge section above) and then, if necessary, modifies all cell velocities by a common factor to raise or lower the estimated water surface elevation until it matches the given water surface elevation.

The flow pattern often changes as channel discharge changes. Consequently, it is important to select either an intermediate discharge for the velocity calibration data set that can be applied to a relatively narrow range of flows or to select two or more velocity calibration data sets depending upon the discharge range being simulated and the rate at which the flow pattern changes. For the Missouri River application, two velocity calibration data sets were collected, one near the upper limit of normal operation (navigation season releases—April through November) and one near the lowest discharge (non-navigation season releases—December through March) that would be ordinarily released under most alternatives. Calibration of the IFG-4 program to measured velocities is generally superior to using hydraulic radius for estimating lateral flow patterns (Milhous, Updike, and Schneider 1989).

The lower velocity calibration discharge was applied from the lowest simulated stage-discharge pair to about the midpoint of the flow difference between the two calibration data sets. For the Gavins Point application, the low-flow calibration data set collected at about 11,000 cfs was applied from 6,000 to 18,000 cfs. The high-flow velocity calibration data set was applied from the midpoint discharge to the highest discharge simulated. For the Gavins Point application, the high-flow velocity calibration data set collected at about 30,000 cfs was applied from 18,000 to 50,000 cfs. The preproject channel cross sections did not include any velocity measurements. Channel velocities were predicted by the IFG-4 program based on hydraulic radius for the pre-project channel cross sections.

Channel geometry, velocity, substrate, and discharge information were provided by the MRD from field surveys. From this information, two separate IFG-4 input data sets were developed. One IFG-4 input data set was developed for the discharges covered by the low-flow velocity calibration data sets and one set for the discharges covered by the high-flow velocity calibration data sets. The IFG-4 program generates a binary output data set for each input

data set. The IFG-4 output data sets are composed of tables of cell-by-cell predicted depths and velocities for each cross section and discharge. The IFG-4 binary output data sets were converted to ASCII using the LSTVDX program of the PHABSIM system. The two output data sets associated with each transect were appended after processing by the LSTVDX program. Standard options were used in the IFG-4 program except that the HABTAM-HABTAV method of using vertical velocities instead of average cell velocities was employed. Use of average cell velocities has a tendency to reduce the variability in the data set by reducing high velocities or increasing lower velocities by averaging with less extreme neighboring cells. IFG-4 was run for the sequences of discharges listed in the following tabulation:

Discharge, cfs		
Preregulation	High	Low
6,000	20,000	6,000
8,000	24,000	8,000
10,000	28,000	10,000
12,000	32,000	12,000
14,000	36,000	14,000
16,000	40,000	16,000
20,000	46,000	
24,000	50,000	
28,000		
32,000		
36,000		
40,000		
46,000		
50,000		

An example of IFG-4 output processed by the LSTVDX program is presented in Table 1. Three different sets of IFG-4 data sets were processed. Preproject IFG-4 data sets were generated in which the velocities were based on hydraulic radius since measured velocities were unavailable for these transects. Two postproject data sets were created. The first postproject data set had the calibration velocities stripped out, and the IFG-4 program generated output velocities based on hydraulic radius. The second postproject data set included calibration velocities, and the IFG-4 program predicted output velocities based on measured velocities. For the second postproject data set, velocities were based on cell-specific Manning's  $n$  obtained from the two velocity calibration data sets.

## **Depth and velocity distributions**

The three ASCII-format tables of depth and velocity generated for each transect were then evaluated statistically using the Statistical Analysis System (SAS Institute, Inc., 1988). The following steps were involved in the statistical analysis:

- a. Cell-by-cell information obtained from the LSTVDX program was processed to eliminate cells having zero depths (cells above the water surface) for each transect.
- b. Cells from similar cross-section categories were combined; e.g., all cells from wide transects were placed into a single category and individual cross sections were no longer distinguished.
- c. Depths were rounded to the nearest 0.5 ft and velocities were rounded to the nearest 0.25 fps using the ROUND function of SAS (SAS Institute, Inc., 1988).

PROC FREQ of the SAS was employed to generate percent cumulative frequencies of depth and velocity for each of the three IFG-4 output data sets for each discharge and each separate category of transects. Separate frequencies were generated for depth and velocity for the univariate application. For the bivariate application, a single frequency distribution was generated that combined both variables.

## **Univariate Analysis**

### **Depth-velocity distribution**

Inspection of the cumulative frequency distributions generated by the frequency analysis indicated that they closely followed the general pattern exhibited by the logistic equation. Frequency distributions for depth and velocity for each of the three IFG-4 output data sets (preproject, project without calibration velocities, and project with calibration velocities) for discharge and channel category were then fit to the logistic equation

$$CPD = \frac{K}{1 + \left( \frac{K-F}{F} \right)^{-RX}} \quad (1)$$

where

$CPD$  = cumulative percent composition

$K$  = apparent maximum cumulative percent (usually near 100)

$F$  = percent composition of the first depth or velocity increment

$R$  = rate of change from one cumulative depth/velocity increment to the next

$X$  = midpoint of depth/velocity increment

The fit of the logistic equation to the cumulative frequency distributions (one distribution for each discharge and channel category) was highly significant. Table 2 presents a summary of the statistics for the fit of the logistics equation for the Gavins Point tailwater.

Curve-fitting was employed for three reasons. First, the lower Missouri River is a sand bed stream characterized by zones of uniform depths. However, field observation indicates that these uniform depths may gradually increase or decrease in either the upstream or downstream direction. Distributions of depth and velocity based on curve-fitted data would tend to smooth out the effect of a particularly abundant depth or velocity category. These distributions would thus be less likely to be influenced by the localized characteristics of a specific location on the river and be more likely to represent a generalized feature of the river. This was a particular concern for the Gavins Point reach data, which had relatively few cross sections and could be easily biased by a high percentage of a particular depth or velocity category in the limited selection of cross sections.

Second, curve-fitting allowed the use of functions to describe each of the distributions. Functions can be stored, adjusted, and manipulated more efficiently than raw data. Third, with curve-fitting, the cumulative frequency distribution of intermediate discharges (discharge increments not simulated) could be estimated by linear interpolation of the coefficients between neighboring discharges.

Corrections to the preproject velocity predictions were made by estimating the error associated with use of hydraulic radius to predict velocity distributions on project data. The project IFG-4 data sets can be used to evaluate the error associated with the use of hydraulic radius to estimate velocity by running the IFG-4 program with and without the velocity calibration data sets. The differences (residuals) between the velocity cumulative frequency distributions represent the error in use of the hydraulic radius to predict velocity. Inspection of the patterns in the residuals indicated that each could be fit by a quadratic equation.

It was decided that adding back the residuals in the form of a quadratic equation (Figures 4-6) to the preproject data set would provide the most accurate estimate of the preproject cumulative velocity distribution because the preproject cross sections were at or very near the locations of the project cross sections, the river had not moved or meandered substantially, and channel top widths had not changed dramatically.

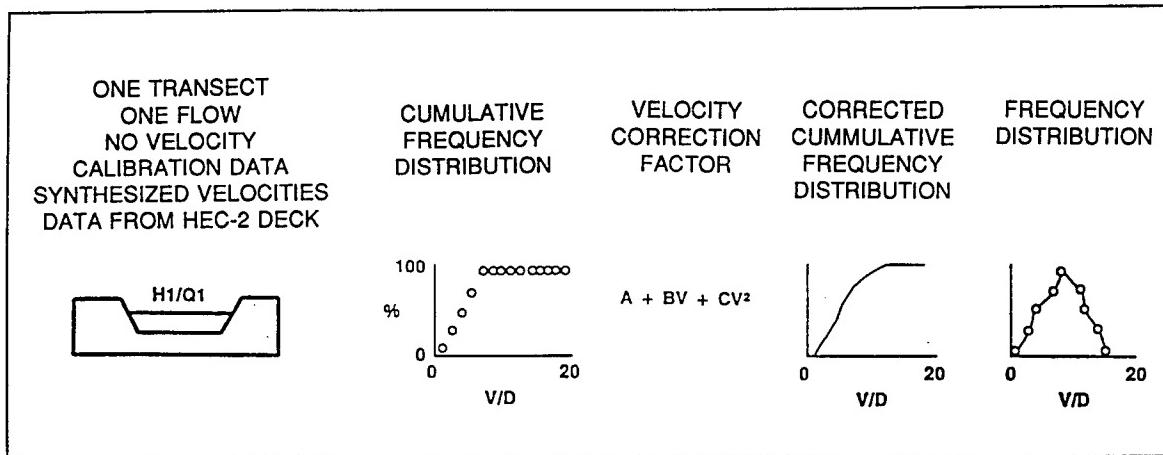


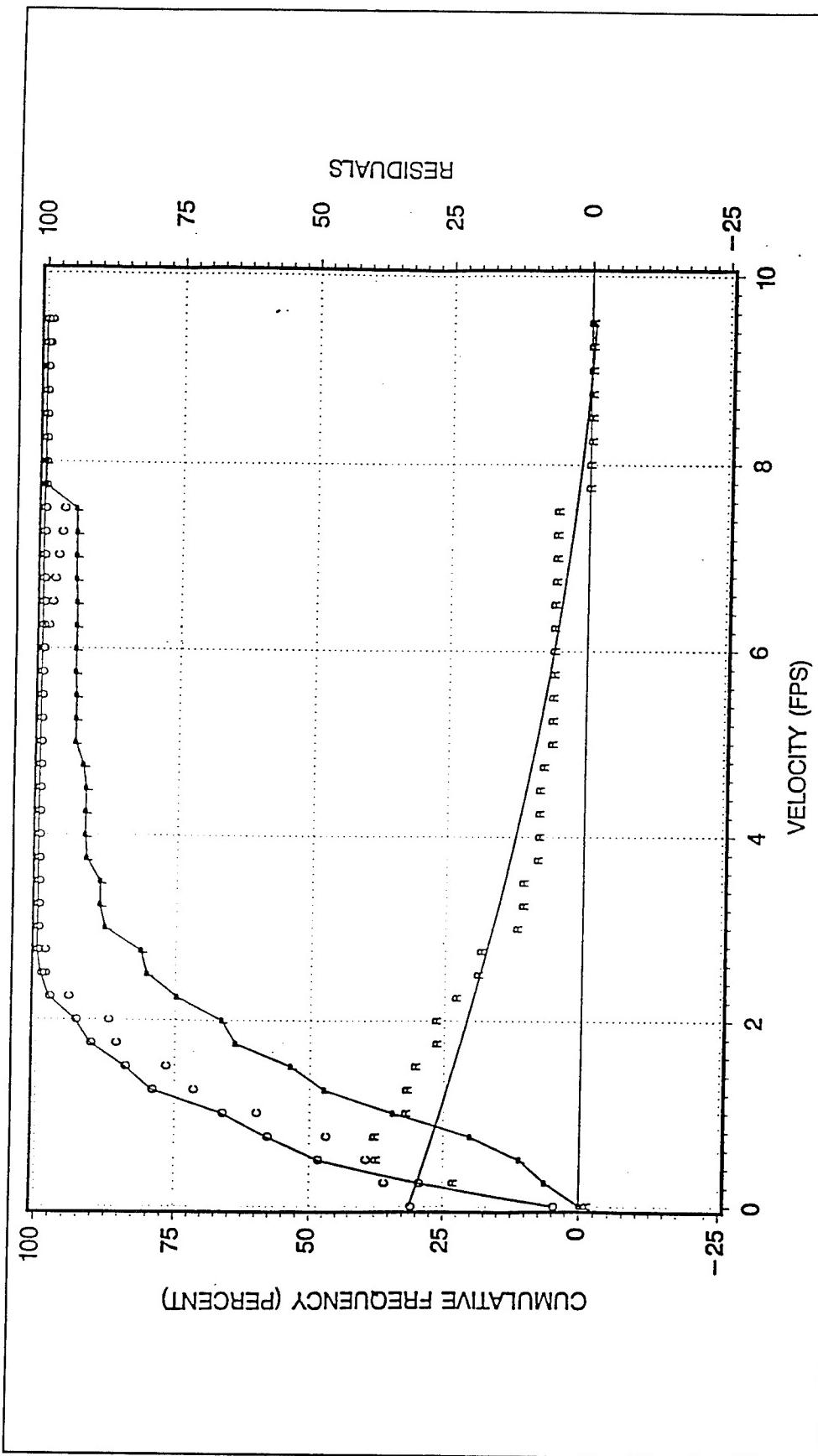
Figure 4. Depiction of method used to correct the CSRS velocity distributions. The cumulative frequency distribution, represented by the logistic equation, is corrected using a quadratic equation derived from analysis of project data with and without velocity calibration data. A frequency distribution is then obtained from the corrected cumulative frequency distribution

If the study objective had been restricted to the ranking of alternatives to a standard, velocities based on hydraulic radius would have been used for both the CSRS and project channels. The same velocity bias would occur in both the CSRS and the project alternatives and, therefore, the relative ranking of alternatives should not be affected. However, the results from this study may also be employed for river restoration, and thus the velocities predictions should be as accurate as possible.

At this point in the analysis using the RCHARC, a discharge-specific and channel category-specific cumulative frequency distribution for depth and velocity (corrected as described above) for the preproject transects was available along with corresponding information for the project channel alternatives. Simple frequency distributions were derived from the cumulative frequency distributions by subtracting from each cumulative depth or cumulative velocity increment the cumulative increment immediately preceding it (e.g., Figures 7 and 8). The final product of this step was discharge-specific simple frequency distributions of depth and velocity for each channel category within the tailwater. Additionally, by summing the top widths of each cell for each channel category within the tailwater, it was also possible to estimate the discharge-specific top widths associated with the preproject and project channels. Discharges were rounded to the nearest thousand cubic feet per second.

### Relative impacts of each project alternative

The depth and velocity distributions associated with each project alternative were expressed differently from the depth and velocity patterns associated with the CSRS's. Depth and velocity distributions associated with each alternative were not assessed directly, but rather interpolated from incremental sequences



**Figure 5.** Comparison of the velocity distributions made at a 6,000-cfs discharge: with calibration velocities (O), without calibration velocities and velocities predicted from hydraulic radius (P), and with the velocity corrections (C). The corrections were obtained by nonlinear regression of the differences (R) between the with- and without-velocity calibration data sets. The line without symbols represents the quadratic equation that was fit to the differences and then added back to the cumulative frequency obtained without using the velocity calibration data sets

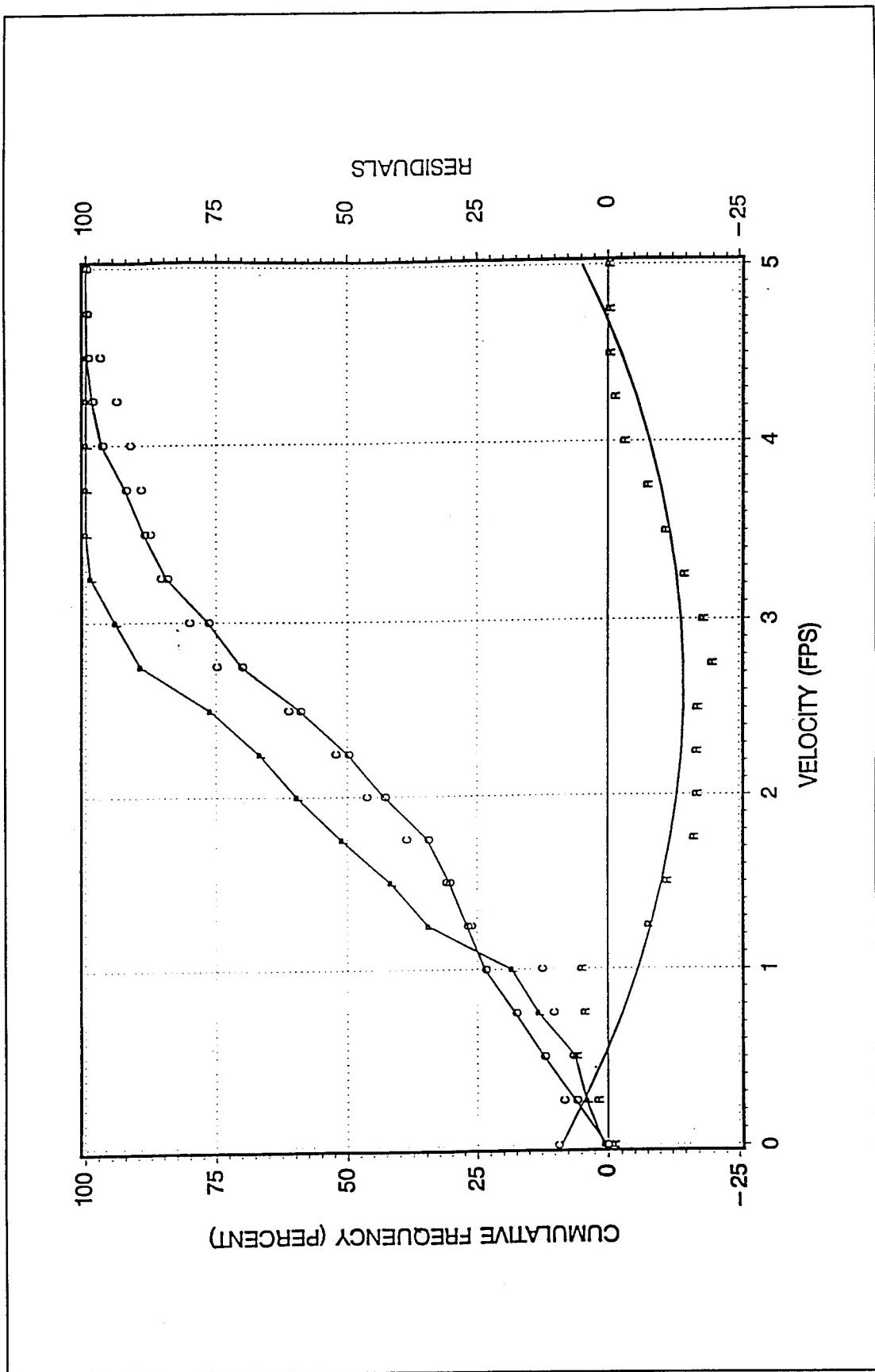


Figure 6. Comparison of velocity distributions made at a 50,000-cfs discharge (symbols as defined for Figure 5)

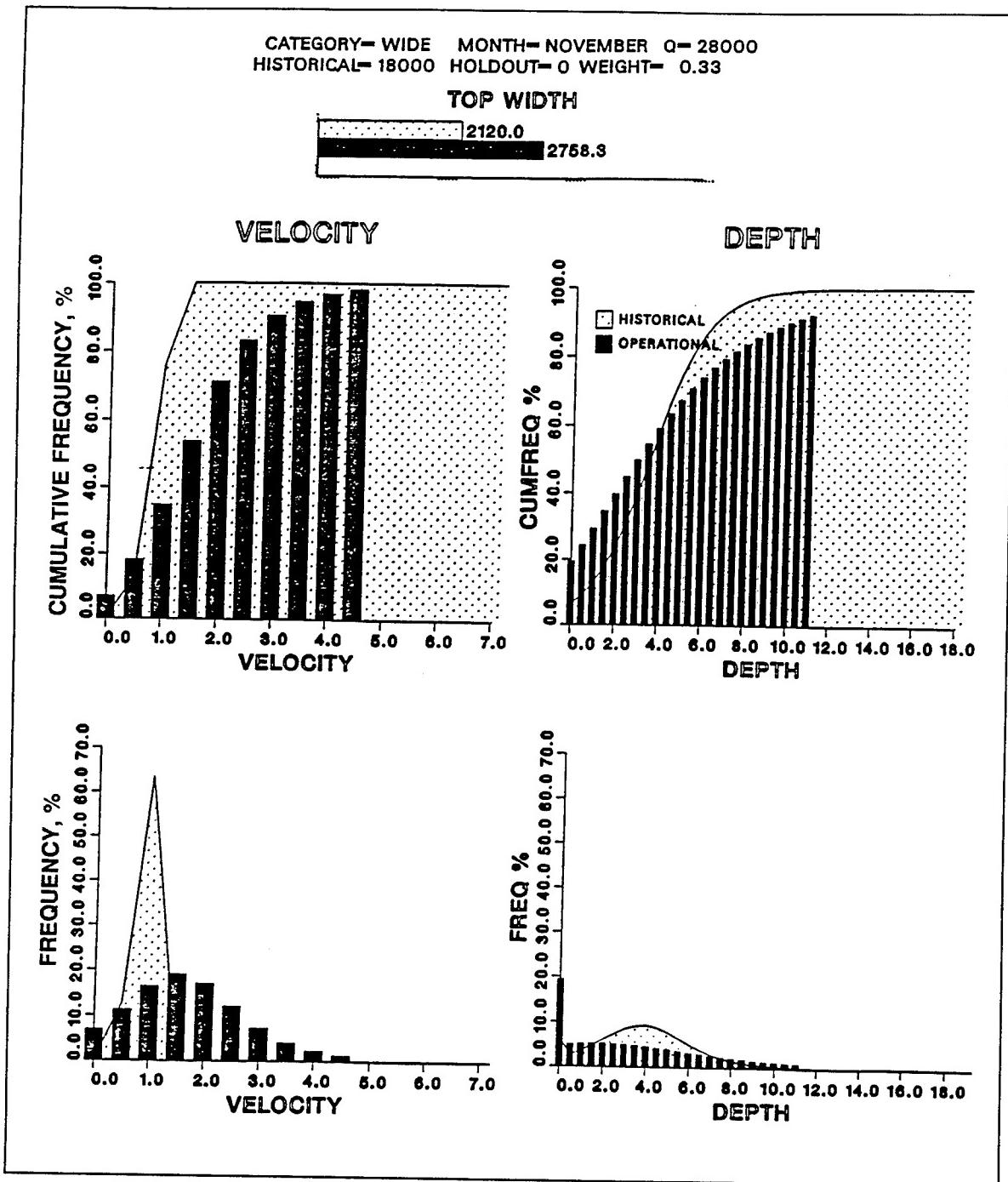


Figure 7. Comparison of the depth and velocity frequencies between the CSRS at a discharge of 18,000 cfs (historical) and project channel conditions at a discharge of 28,000 cfs (operational) for the wide channel category. Note the greater depths and lower velocities in the historical channel than in the project channel. The velocity distributions and depth distributions do not necessarily have to mass balance if the top widths are substantially different

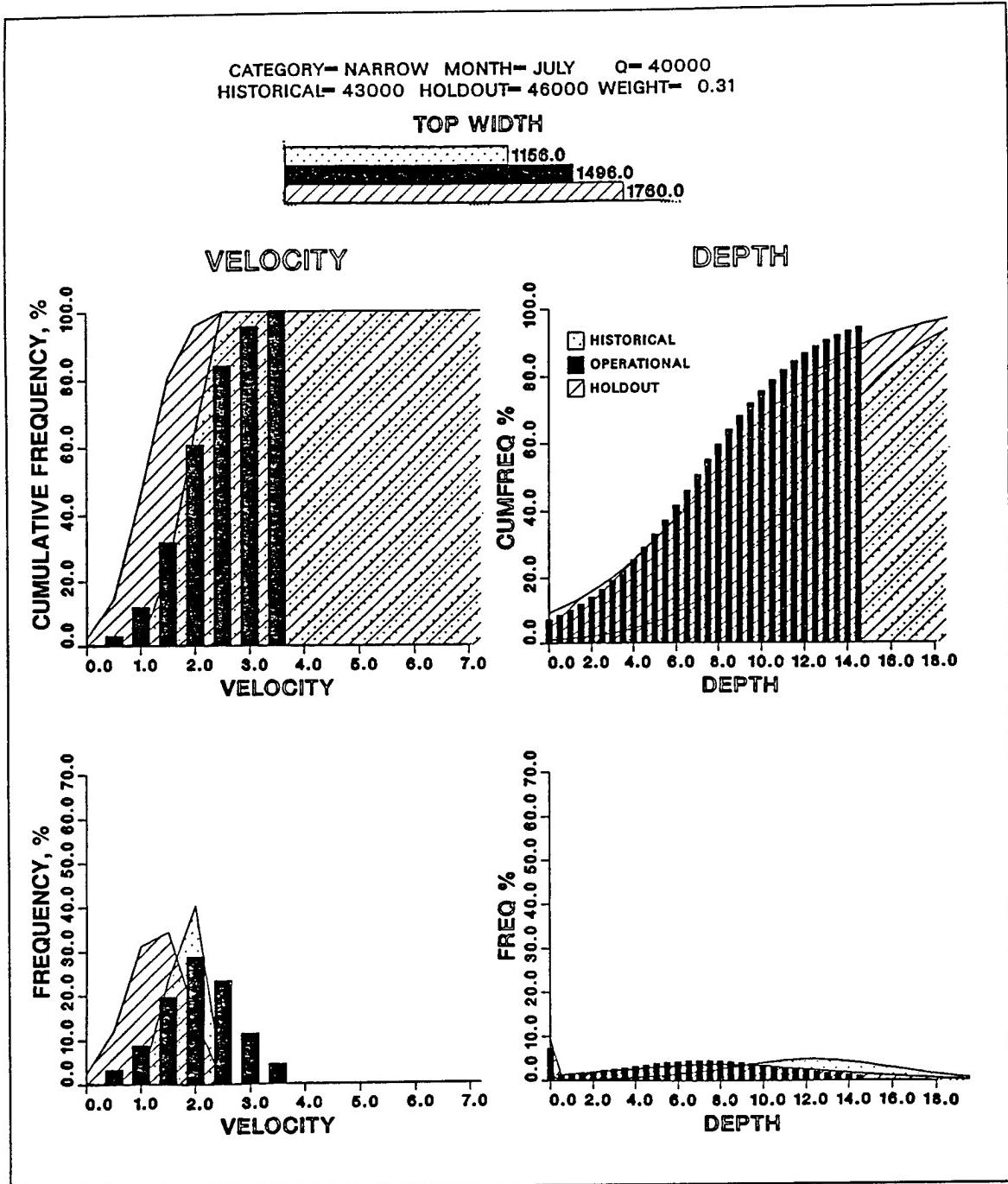


Figure 8. Comparison of the depth and velocity frequencies between the CSRS at a discharge of 43,000 cfs, project channel at a discharge of 40,000 cfs, and special holdout run to simulate a year as though the dams were not in place

of flows for each site. For example, project alternative flows were simulated for 6,000, 8,000, 10,000, 12,000, 14,000, 16,000, 20,000, 24,000, 28,000, 32,000, 36,000, 40,000, 46,000, and 50,000 cfs for the Gavins Point reach. The lower flow limit was determined by the limitations of the HEC-2 model to simulate flows less than 6,000 cfs, and the upper limit was determined by the

discharge at which overbank flow occurred. The MRD felt that stages for overbank flows could not be accurately simulated. The CSRS's were characterized by distributions of depth and velocity associated with specific water years on a month-by-month basis. For example, the depth distribution for January (11,000 cfs) in a median water year was obtained by linear interpolation of the  $R$  and  $K$  coefficients of the logistic equation for 10,000 and 12,000 cfs. The water-year-specific CSRS was described in terms of the depth and velocity distribution for each month.

The relative value of each alternative flow at a particular month for one of the three CSRS's was obtained by determining the similarity between the depth/velocity patterns associated with monthly CSRS flows and the depth/velocity increments used to evaluate the postproject channel (detailed description of the steps is shown in Figures 4, 9, 10, and 11). The impact of a particular operational alternative for 1 year could be determined by looking up its similarity to preproject distributions on a table of incremental project discharges versus preproject discharges (Appendix A). Each of the 12 resulting similarities is summed to determine the impact of that alternative. The process can be expanded to include any number of months. The correlation coefficients were rescaled to range from 0.0 to 1.0 instead of -1.0 to 1.0.

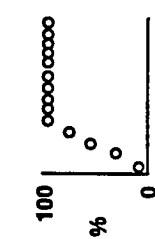
A variety of similarity metrics can be employed; however, for this analysis, the Pearson product-moment correlation analysis was used to relate how the depth or velocity categories varied between the CSRS and a series of incremental project flows. Other statistics were evaluated at the beginning of this study, but the ranking of coefficients of flow increments versus a particular historic flow did not change. Also, as pointed out by Clifford and Stephenson (1975), most methods of determining similarity produce the same general patterns of results. However, further use of the RCHARC may determine that other statistics are more suitable.

### **Correction for top width**

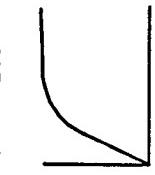
It is possible to have similar depth or velocity distributions (habitat quality) but very different top widths (habitat quantity). To account for differences in quantity between the CSRS and the project alternatives, the correlations between the CSRS's and the project alternatives were adjusted by a coefficient keyed to the difference between the preproject top width and the top widths associated with each alternative flow increment. For example, if the top width of a historical flow was identical to a particular flow increment, then there would be no adjustment of the correlation coefficient. However, if the pre-project top width at a flow associated with a particular month was less than a particular flow increment, then the correlation coefficient was reduced by the ratio difference between the two top widths as

NARROW TRANSECT  
3 DIFFERENT H/Q's  
2 VELOCITY CALIBRATION  
DATA SETS  
STAFF GAGE / HEC-2 DECK

CUMULATIVE  
FREQUENCY  
DISTRIBUTION



FITTED CUMULATIVE  
FREQUENCY  
DISTRIBUTION  
EQUATION



FREQUENCY  
DISTRIBUTION

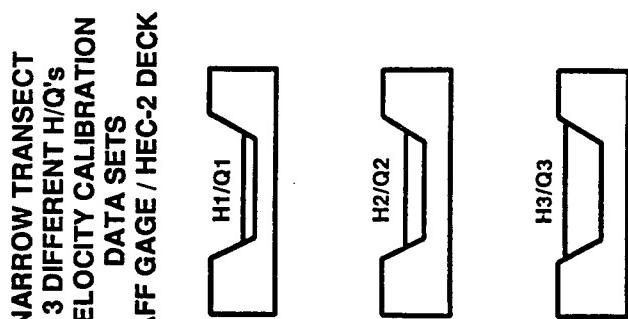
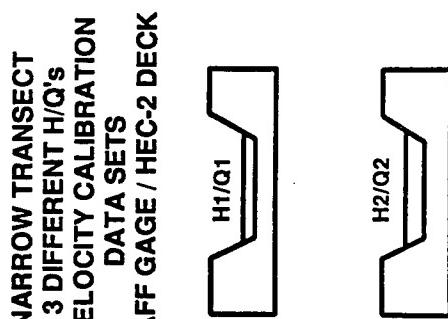
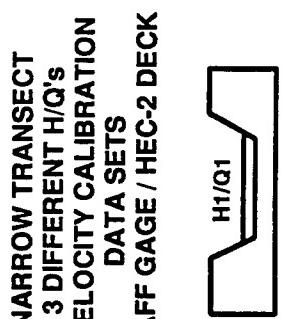
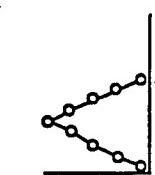


Figure 9. Cumulative frequency distribution is developed from the depth and velocity information from one cross section for each of three discharges. The cumulative frequency is fitted to the logistic equation and a smoothed velocity and depth distribution is developed from each fitted cumulative frequency distribution. In this case, the analysis is performed for only 1 month

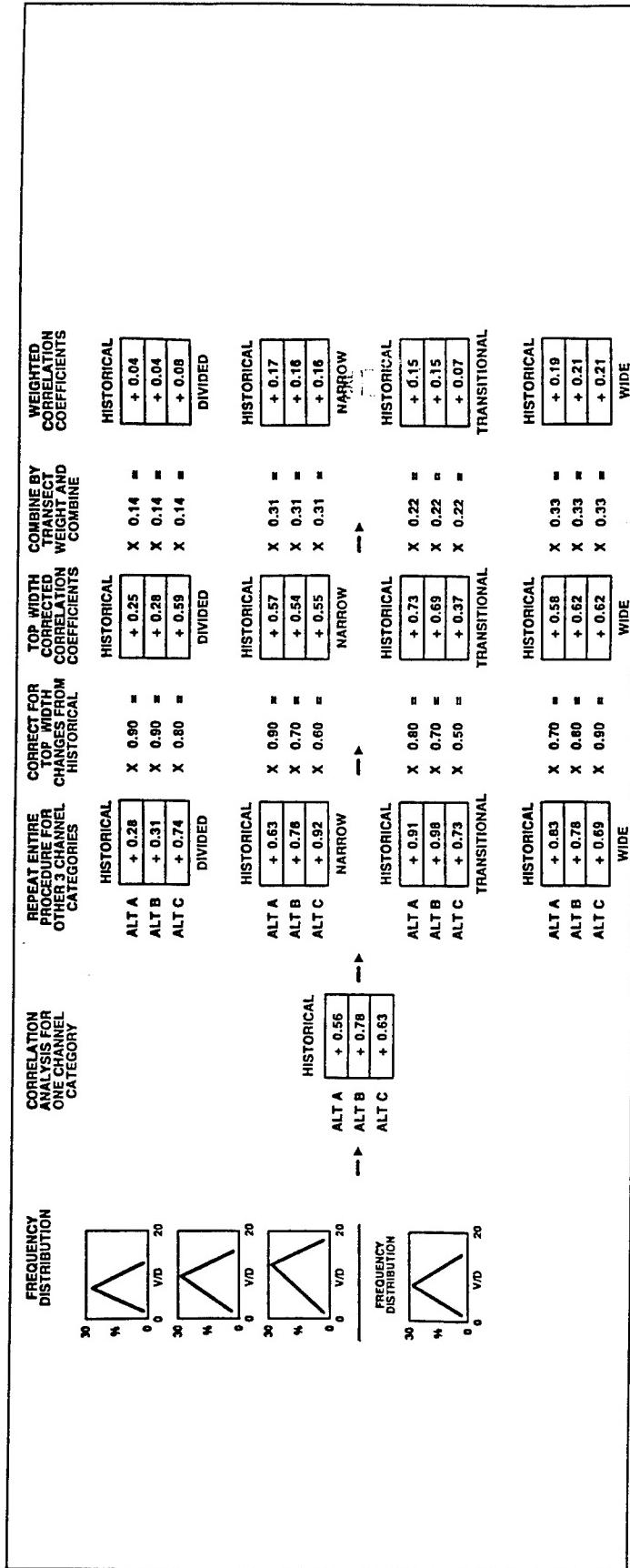


Figure 10. CSRS frequency distribution derived in Figure 4 is below the horizontal reference line on the left side of this plot. The frequency distributions from Figure 9 for each alternative are located above the horizontal reference line. Correlation analysis is used to relate the similarity of each of the project alternatives to the CSRS. The 1 by 3 correlation table shown in column 2 represents only one channel category. The Gavins Point analysis used four categories of transects (represented by column 3). Each of the correlation coefficients is adjusted for differences in top width (as a percentage) between the CSRS and each project alternative to derive a series of top width-corrected correlation coefficients (column 5). Each of the top width-corrected correlation coefficients is then weighted by the linear percentage of the channel that each represents. Critical reaches can be weighted more heavily if necessary

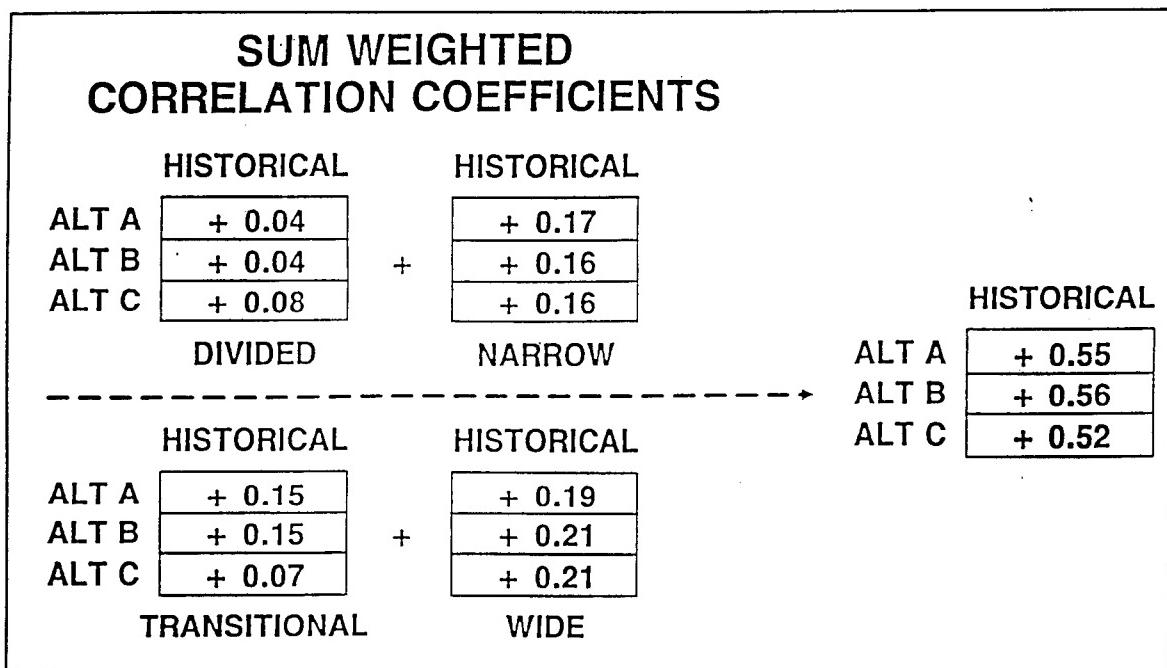


Figure 11. Each of the weighted correlation coefficients from the rightmost column of Figure 10 is then summed to represent a single value of impact for each of the three alternatives. For this example, covering Figures 4, 9, 10, and this figure, the example was performed for only 1 month. For multiple months (or other time-steps), the correlation coefficients would be summed across rows to develop a single value of impact

$$COR\_COEF = COEFA * \left( 1 - \frac{PROJ\_TOP - PRE\_TOP}{PROJ\_TOP} \right) \quad (2)$$

where

*COR\_COEF* = adjusted correlation coefficient

*COEFA* = unadjusted correlation coefficient

*PRE\_TOP* = CSRS (preproject) top width

*PROJ\_TOP* = project top width

If the preproject top width at a flow associated with a particular month was greater than a particular flow increment, then the correlation coefficient was computed as

$$COR\_COEF = COEFA * \left( 1 - \frac{PRE\_TOP - PROJ\_TOP}{PRE\_TOP} \right) \quad (3)$$

For Gavins Point tailwater, 48 tables of correlation matrices were generated, categorized as follows:

- a. Three different water years (median, low, and high).
- b. Two flow variables (depth and velocity).
- c. Four channel categories (divided, narrow, transitional, and wide).
- d. Two top width categories (adjusted and unadjusted).

The different channel categories for Gavins Point could be combined by weighting each category by the percent distance of the reach that it represented and summing the correlation coefficients (Figure 11).

## Bivariate Analysis

### Depth-velocity distributions

The following steps were involved in creating bivariate data sets of depth-velocity profiles for the Gavins Point reach of the Missouri River:

- a. Cell-by-cell information obtained from the LSTVDX program was processed to eliminate cells above the water surface for each transect.
- b. Cells from similar cross-section categories were combined (as in the univariate analysis), and individual cross sections were no longer distinguished. In addition to the channel categories (divided, narrow, transitional, and wide), transects were classified as to proximity to the dam (closer than 20 miles is near; farther than 20 miles is far). Also, channel categories were combined for analyzing overall trends within the Gavins Point reach.
- c. Depth and velocity values were converted to metric (1 ft = 0.3048 m) and rounded off (depth to nearest 0.5 m, velocity to nearest 0.2 m/sec). Discharge alternatives were rounded to the nearest 1,000 cfs.

Bivariate frequency distributions (depth-velocity) per discharge were generated using the SAS FREQ procedure, with each depth-velocity increment across each section weighted by the water surface area (cell width) it represented. The sparse option was used in the FREQ procedure to write out all possible depth-velocity combinations. Frequency distributions were created in this manner for all discharges per channel category for both project and pre-project data sets.

Rounding the depth and velocity values resulted in a spiking of the frequency distribution data at the rounded increments. To alleviate this inherent

rounding problem, the sharp peaks in the bivariate data set were smoothed by taking a running average of three values of the percent frequency variable.

### Relative impacts of each project alternative

Project alternative flows were simulated for the same 14 discharges as in the univariate analysis, with historical depth-velocity frequency distributions interpolated from incremental sequences of flows. The CSRS's were characterized by bivariate distributions associated with monthly flows for a median water year.

To examine the extent of similarity (or dissimilarity) between project and preproject depth-velocity profiles, the quantitative Canberra metric coefficient (Lance and Williams 1966, 1967) was employed. The Canberra coefficient technique was chosen because its resemblance value reflects high and low scoring attributes evenly. The metric coefficient is based on the average of a series of fractions relating to interentity resemblance, thus having inherent attribute standardization (Boesch 1977). The dissimilarity Canberra metric coefficient has the form:

$$A_{jk} = (1/n) \sum_{i=1}^n |X_{ij} - X_{ik}| / (X_{ij} + X_{ik}) \quad (4)$$

where

$A_{jk}$  = Canberra metric coefficient

$n$  = total number of attributes excluding all double zero matches

$X_{ij}$  = preproject frequency distribution per depth-velocity increment

$X_{ik}$  = project frequency distribution per depth-velocity increment

In cases where one attribute within a match is zero, a value of 0.01 is substituted to ensure that varying attribute differences are reflected accordingly. The Canberra coefficient is defined on the range  $0.0 \leq A_{jk} \leq 1.0$ , where  $A_{jk} = 1.0$  indicates maximum dissimilarity. To convert the metric to a similarity measure, simply subtract  $A_{jk}$  from 1. All Canberra coefficients reported here have been converted to measures of similarity to match the correlation coefficients of the univariate analysis.

As in the univariate analysis, the difference in top width between the historical conditions and the project alternatives was accounted for when describing the degree of similarity between the two data sets. Refer to Part III for the top width adjustment equation.

For the Gavins Point reach, Canberra similarity matrices were generated in the bivariate analysis for a median water year, categorized as follows:

- a. Four channel categories (divided, narrow, transitional, and wide).
- b. Two top width categories (adjusted and unadjusted).

To determine impact for the Gavins Point reach at a single discharge, the four channel categories were combined by weighting each category by the proportional distance of the tailwater that it represented and summing the Canberra coefficients (Table 3). Monthly median historical depth/velocity frequency distributions were linearly interpolated; i.e., median discharge for April = 38,000 cfs, so frequency distributions were calculated using discharges of 36,000 and 40,000 cfs. Top widths associated with median monthly flows were interpolated in a similar fashion.

## 4 Trends and Patterns in the Results

---

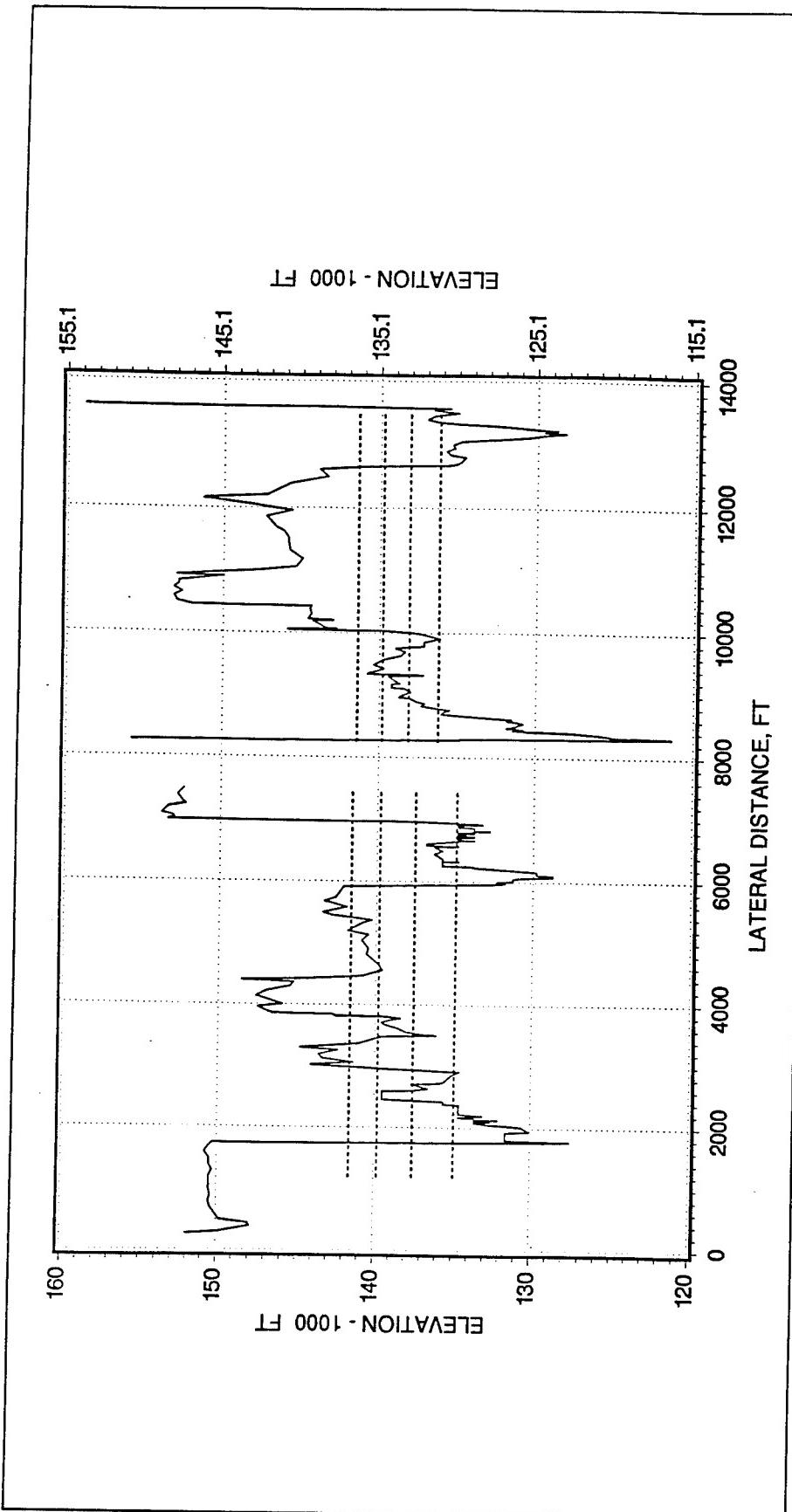
Several channel processes were occurring in the Gavins Point tailwater that have habitat implications. Degradation of the channel was occurring near each of the dams because the dam disrupted the downstream transport of sediment. The degraded sediment was transported downstream of Omaha, NE, where it was deposited in the aggrading reaches of the river. These observations have been made on numerous occasions and are not unique to this study; however, when viewed from the perspective of an RCHARC analysis, they provide a unique insight into habitat conditions in the Missouri River.

The habitat changes in the Missouri River are best described by comparing CSRS (preproject) transects with project transects at similar locations (Figures 12-15). Several significant features become apparent. First, the elevations in the project channel have all been reduced by about 5 ft from the CSRS channel. Note also that the stage-discharge is in general compressed in the project cross sections compared to the CSRS cross sections. The compression is greatest for the two transects having the greatest top width and least for the two transects having the least top width. Perhaps the lack of sediment input to this reach has allowed the releases from the dam to scour out a more hydraulically efficient channel.<sup>1</sup> In support of this observation, the narrow transects are widening, and wider transects are narrowing when the project top widths are compared to the preproject system as though the river is "ditching." Ditching appears to be occurring in the wider reaches that offer the greatest habitat diversity and concomitantly should have an effect on the fish community (Kallemyen and Novotny 1977).

The depths associated with the lowest discharge in the project channel are greater than the depths associated with lowest discharge in the preproject channel (Figures 12-15). The cause of the change in depths at low discharge between the preproject and postproject channel is unknown. However, the deeper initial depths are compensated by the reduced increase in stage as discharge increases in the project channel. By the time the project flows reach

---

<sup>1</sup> Personal Communication, March 1992, Brad R. Hall, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.



**Figure 12.** Comparison of a cross section in the divided category collected prior to impoundment (left) with project cross section (right) collected at the same location (Gavins Point, RM 783.6), but after many years of regulation. The left ordinate applies to the preproject transect, and the right ordinate applies to the project channel. The elevations have been reduced by 1,000 ft. The two elevation scales have been adjusted so that both are aligned to the water surface elevation at 30,000 cfs to enhance comparability of the stage patterns. Note that project elevations have been reduced by about 5 ft because of degradation. Note also the compression of the stage-discharge relationship in the project channel. (Horizontal water surface elevation reference lines at 6,000, 16,000, 32,000, and 50,000 cfs)

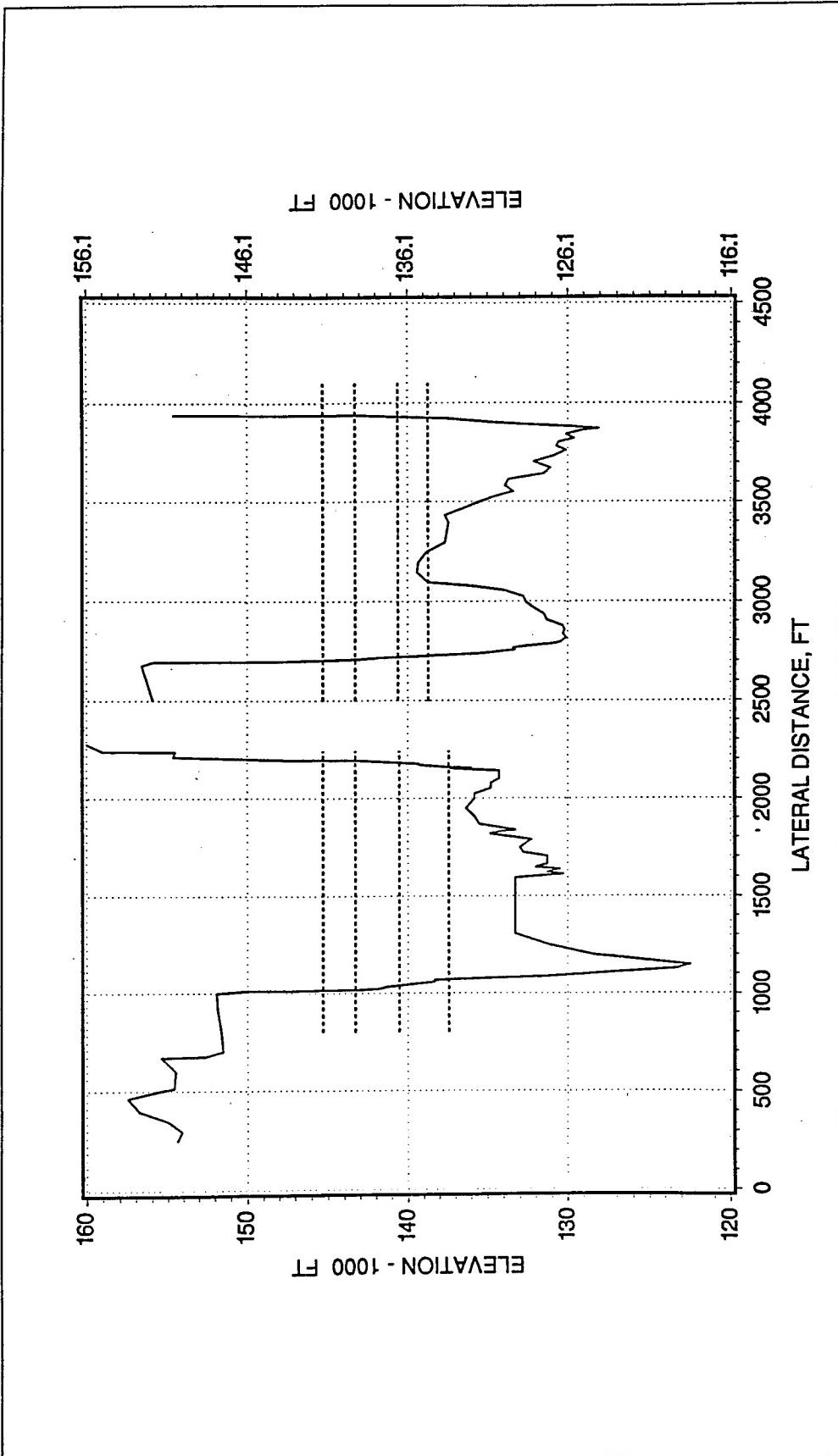


Figure 13. Comparison of a cross section (RM 786.8) in the narrow category collected prior to impoundment (left) with that after many years of regulation (right). Configuration of this plot is the same as in Figure 12. Note that the project elevations have been reduced by about 5 ft by degradation but that the stage-discharge relationship has not been significantly compressed

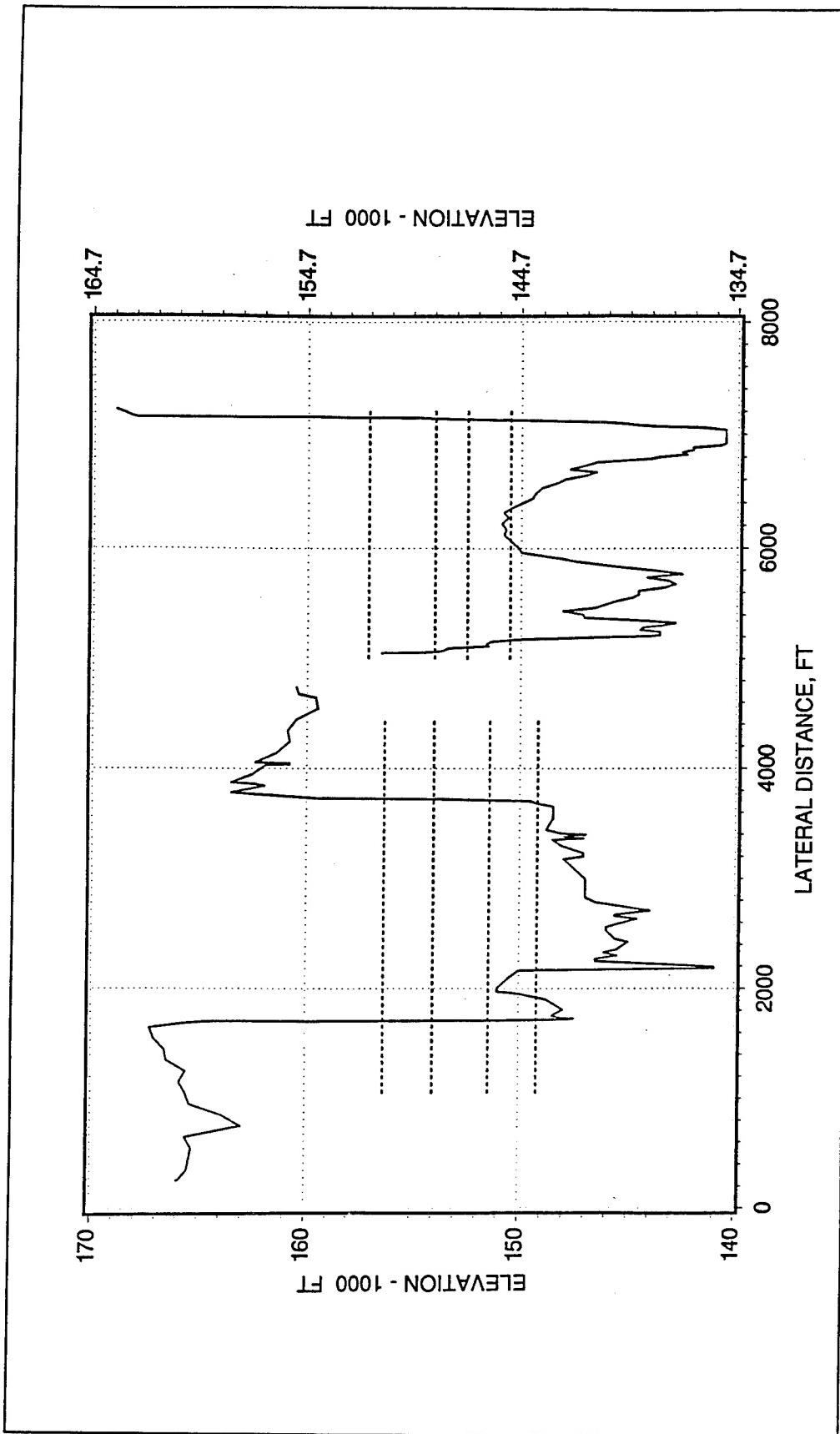


Figure 14. Comparison of a cross section (RM 797.5) in the transitional category collected prior to impoundment (left) with that after many years of regulation (right). Configuration of this plot is the same as in Figure 12. Note that the project elevations have been reduced by about 5 ft by degradation but that the stage-discharge relationship has not been significantly compressed

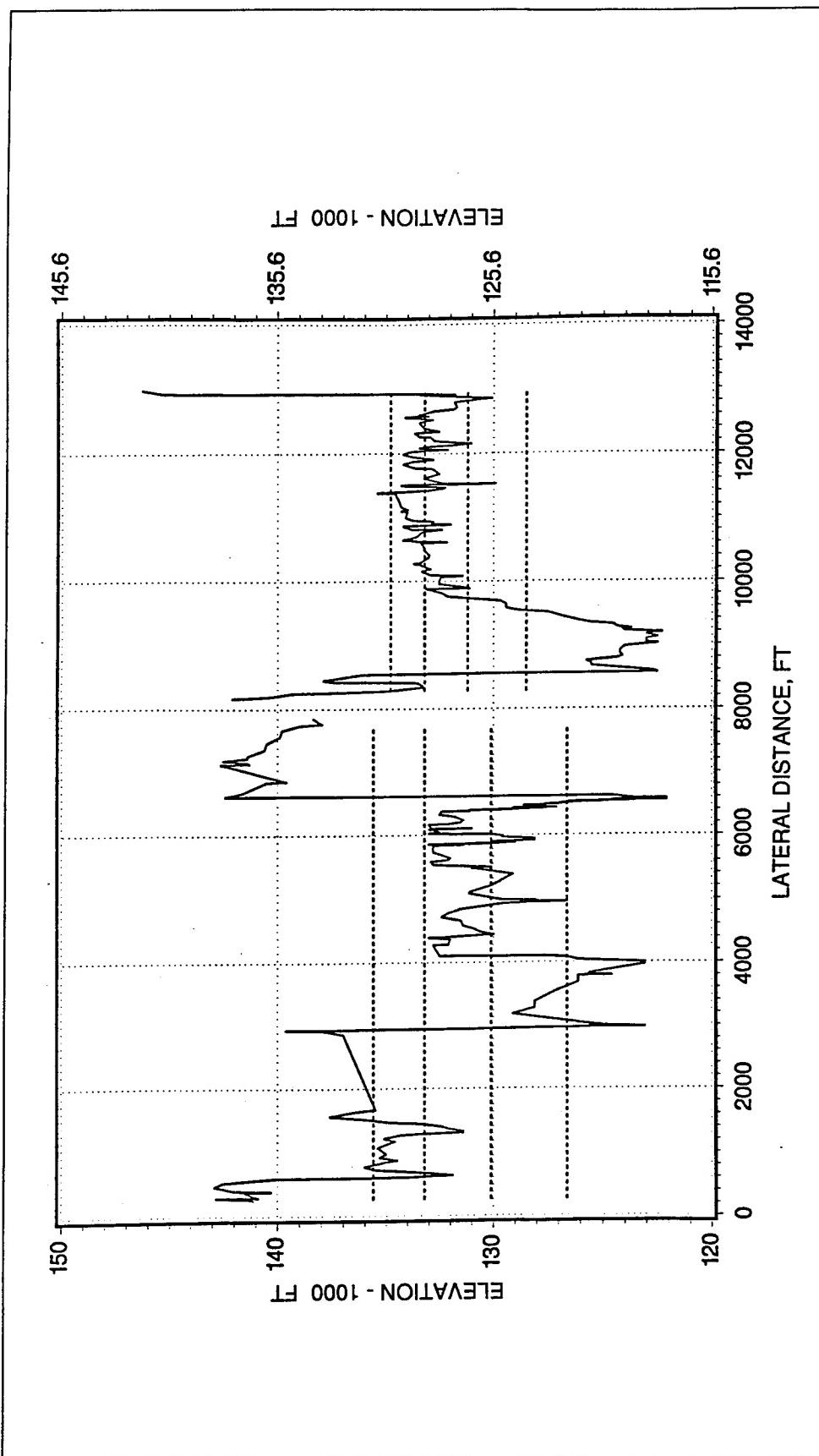


Figure 15. Comparison of a cross section (RM 778.9) in the wide category collected prior to impoundment (left) with that after many years of regulation (right). Configuration of this plot is the same as in Figure 12. Note that the project elevations have been reduced by about 5 ft by degradation and that the stage-discharge relationship has been significantly compressed

50,000 cfs, they appear to have much the same depths as the 32,000-cfs flows in the CSRS. While the observations in the previous two paragraphs are speculative, they do suggest that the degradation has had significant habitat implications.

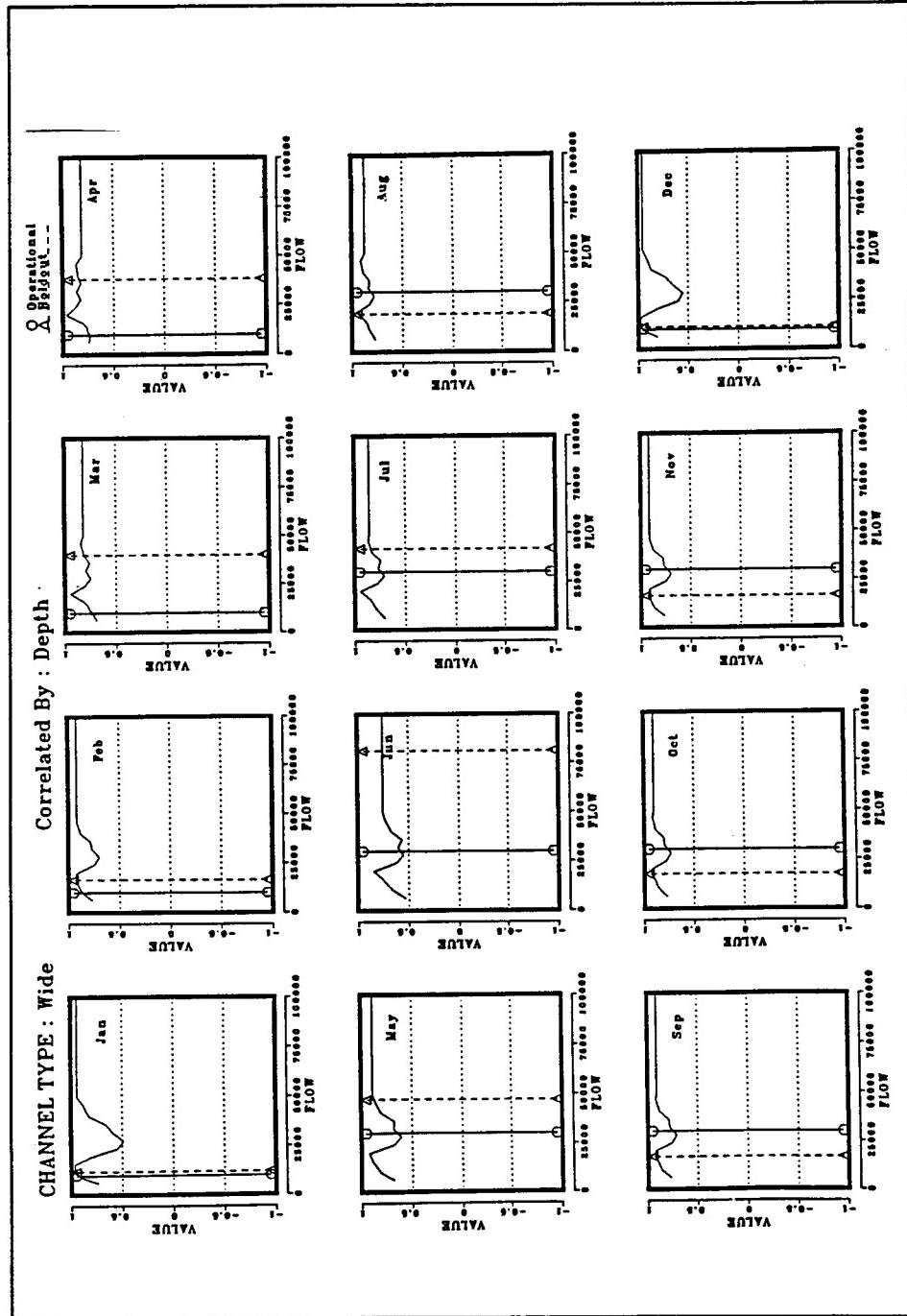
Figures 16-19 present plots at monthly intervals that relate the similarity as correlation coefficients of the historical monthly flows to range of incremental project discharges. Note that the general form of these plots follows the value function format required by MRD to link the “native warmwater riverine fish community” resource category to the other resource categories as part of the Missouri River Water Control Manual Review studies. The flows used for the CSRS are listed in the tabulation in the section “Hydrologic Summaries” under median flows for Gavins Point Dam.

Figures 16 and 17 present top width unadjusted correlation coefficients for depth and velocity, respectively; Figures 18 and 19 present the same information except that the correlation coefficients have been adjusted for deviations from historical top widths. The dotted vertical reference line represents the median flow for each month. The solid vertical reference line on each of the 12 plots represents an arbitrary sequence of monthly flows selected by the authors to represent an imaginary project alternative.

Several trends in the patterns of the correlation coefficients are apparent. First, the correlation coefficients for the top width unadjusted depth correlation coefficients have an apparent bimodal shape. The initial minimum in the correlation coefficients for each month represents the discrepancy in depth observed at the lowest simulated flows. The first peak represents the point at which the depth distributions of the CSRS and project channels converge. Depth increases less quickly with discharge in the project channel than in the CSRS. Consequently, the depths in the CSRS “catch up” to the depths in the project channel. For the wide channel category this appears to happen at about 20,000 cfs.

The correlation coefficients reach a minimum, however, when the discharges in the CSRS for the wide and divided channel categories go full channel (full channel refers to point at which the stage increases enough that all of the channel between the river banks is inundated). There is no corresponding behavior in the project channel. The correlation coefficients then again increase as the flows in the CSRS go higher and increase their depth over the shallow parts of the channel and become deeper like the project channel. The dip in the columns of correlation coefficients corresponds to the threshold when the historical channel acquires a high percentage of shallow depths from going full bank (Figures 12 and 15).

Degradation has also reduced the connectivity of the main channel to chutes and backwaters (Figure 15). The elevations of the highest discharges are inadequate to flood these areas, limiting the availability of shallower water at high discharges. Consequently, side channels and other types of off-channel habitat are no longer a habitat feature of the degrading reaches of the regulated



**Figure 16.** Monthly value functions (constructed from correlation coefficients) for the wide channel category for depth. These functions have not been corrected for top width. The dotted reference line is the median monthly flow for that month, and the solid vertical reference line represents the project alternative depicted in Figure 20. Note the general pattern of bimodal peaks for each month

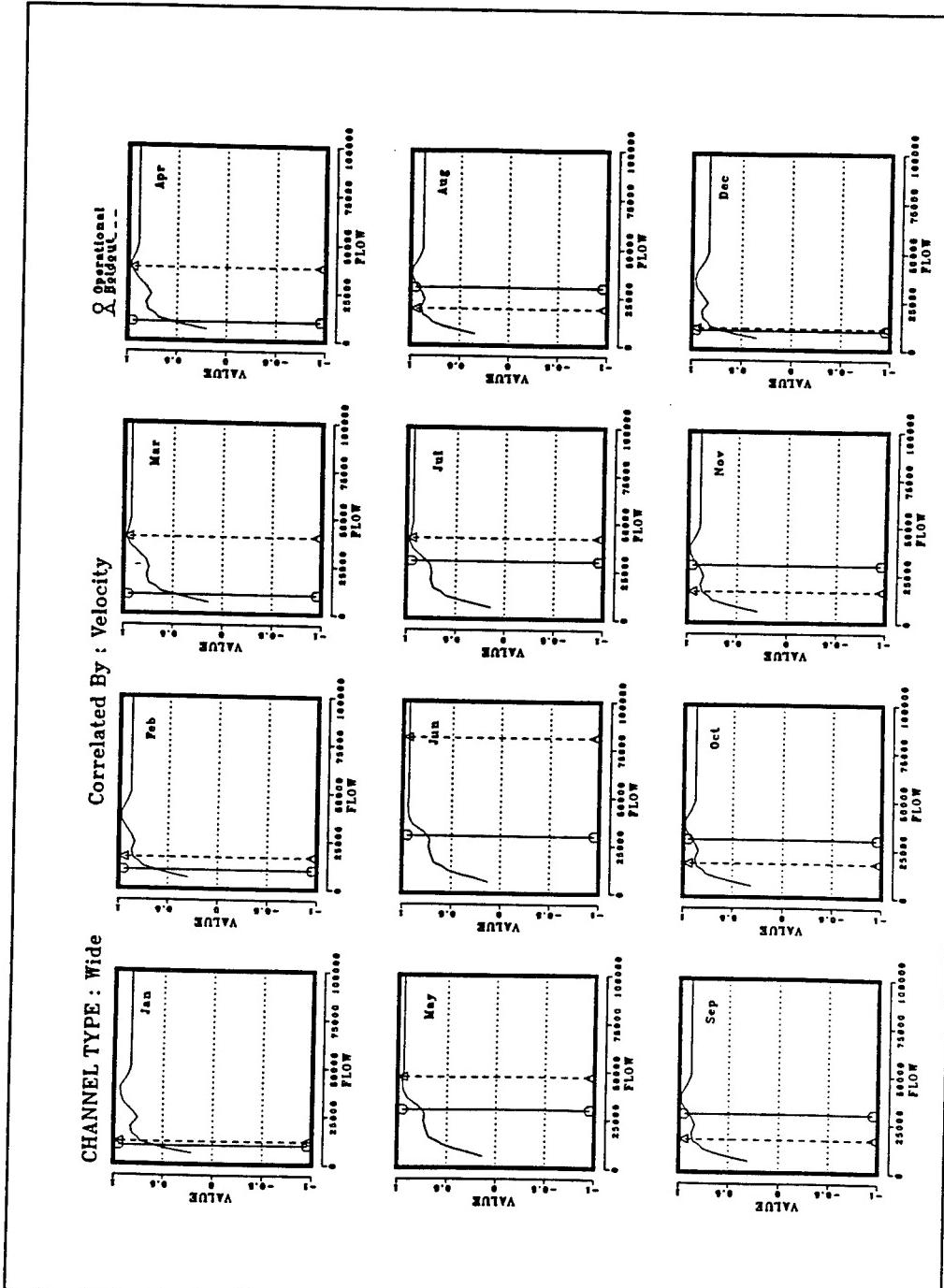


Figure 17. Monthly value functions (constructed from correlation coefficients) for the wide channel category for velocity. These functions have not been corrected for top width. The conventions of Figure 16 are followed in this figure. Note the general pattern of bimodal peaks for each month

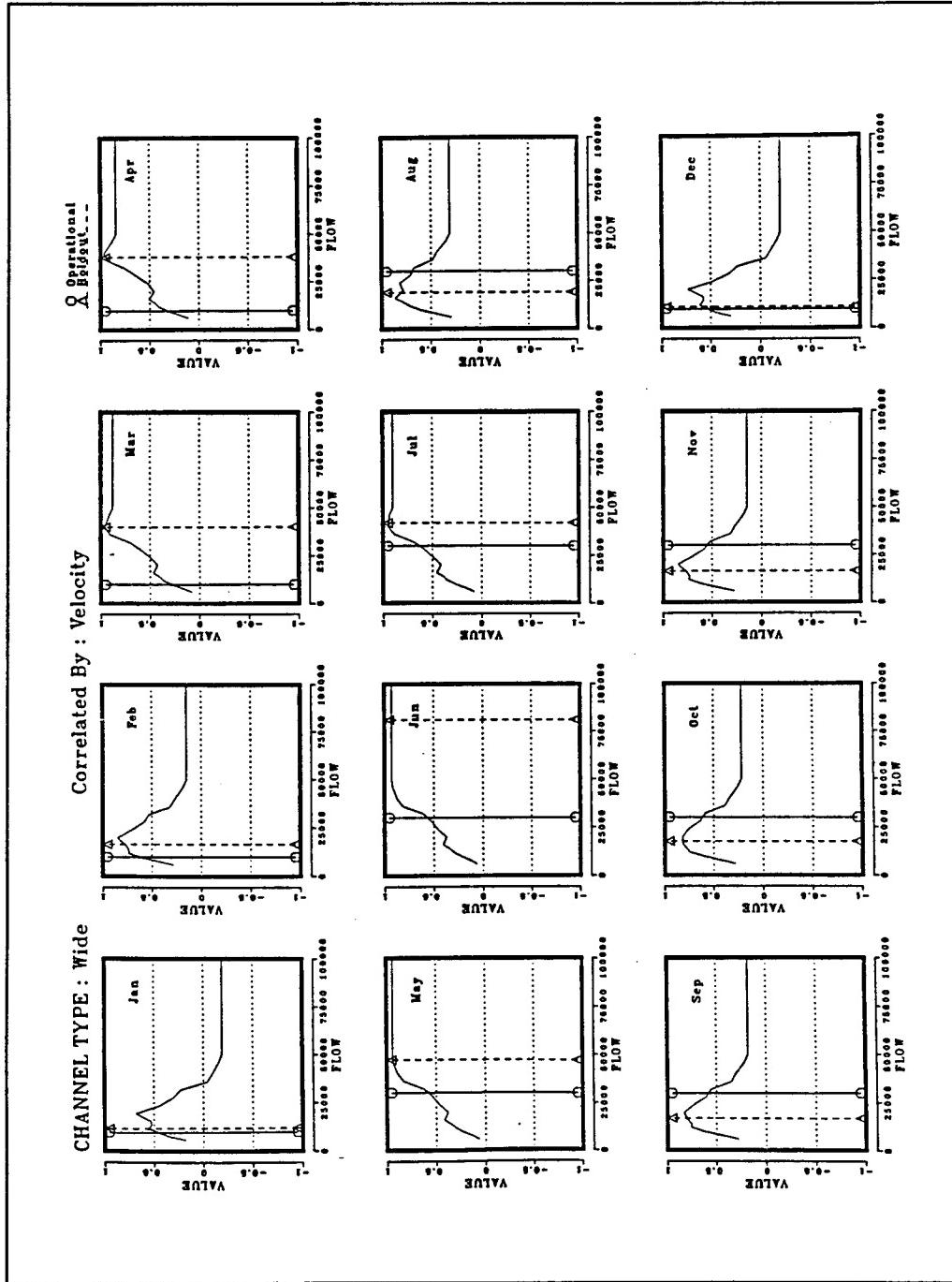


Figure 18. Monthly value functions (constructed from correlation coefficients) for the wide channel category for depth corrected for top width. The conventions of Figure 16 are followed in this figure. Note that bimodal peaks can be observed even through the top width corrections

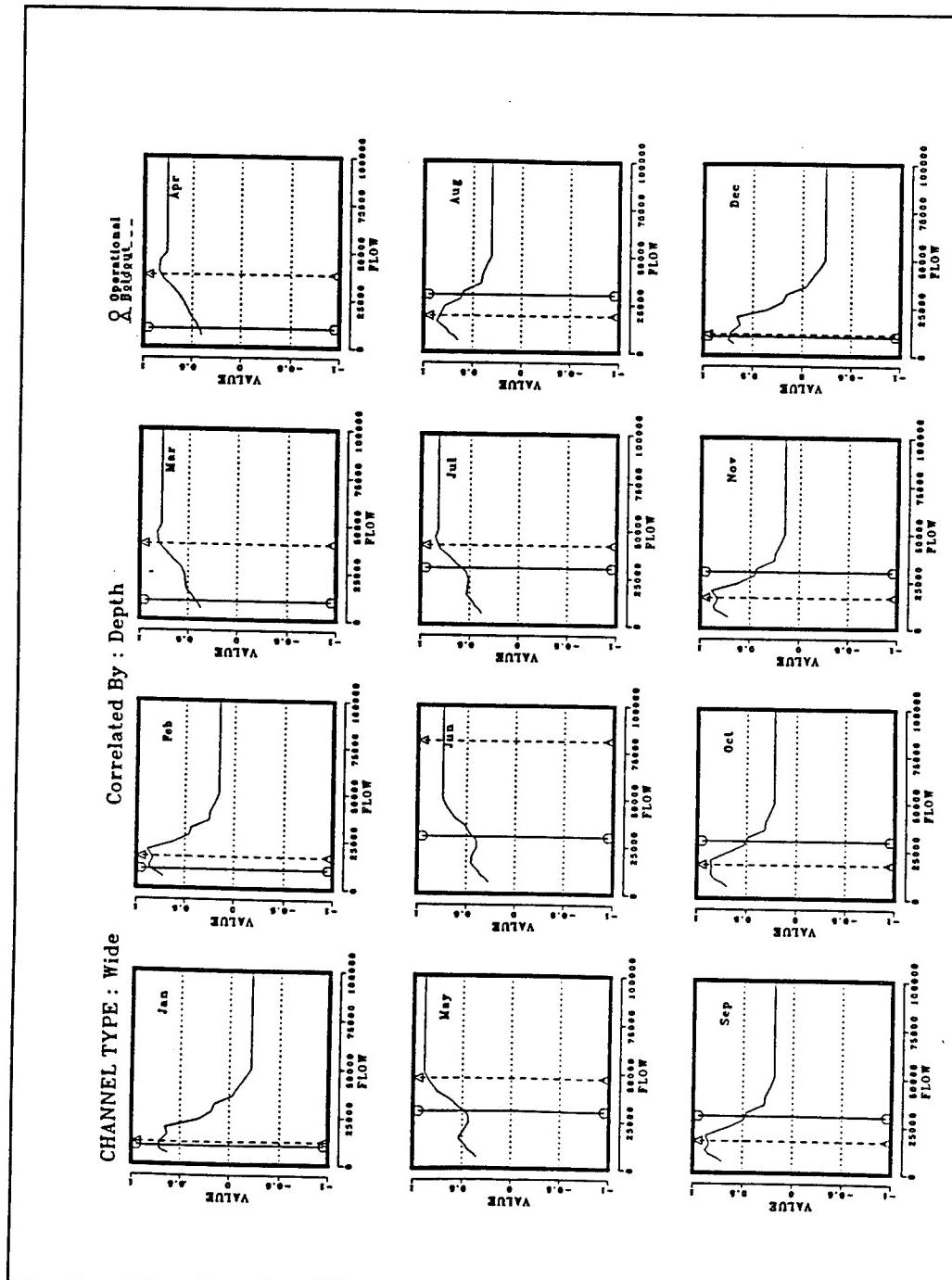


Figure 19. Monthly value functions (constructed from correlation coefficients) for the wide channel category for velocity corrected for top width. The conventions of Figure 16 are followed in this figure. Note that bimodal peaks can be observed even through the top width corrections

Missouri River during high discharges. Overbank areas are not available for fishes, and organic matter produced in the river margins no longer can be inundated by the flows. Riverine fishes that utilize this habitat feature could be impacted negatively.

The compression of the stage-discharge relationship in the Gavins Point tailwater and the relatively large cross-sectional area available at lower flows in the project reach, compared to the preproject reach, also distort the relationship between mean cross-section velocity and stage. At low discharge, the water velocity in the project river is reduced from the water velocity in the CSRS. However, because of the compression of the stage-discharge relationship in the project channel, eventually the average depth of the project reach will be the same as that of the CSRS as discharge increases in both channels. For depth in the wide channel category, a discharge of 14,000 cfs in the project channel has about the same depth distribution as a discharge of 25,000 cfs in the main channel (Figure 15).

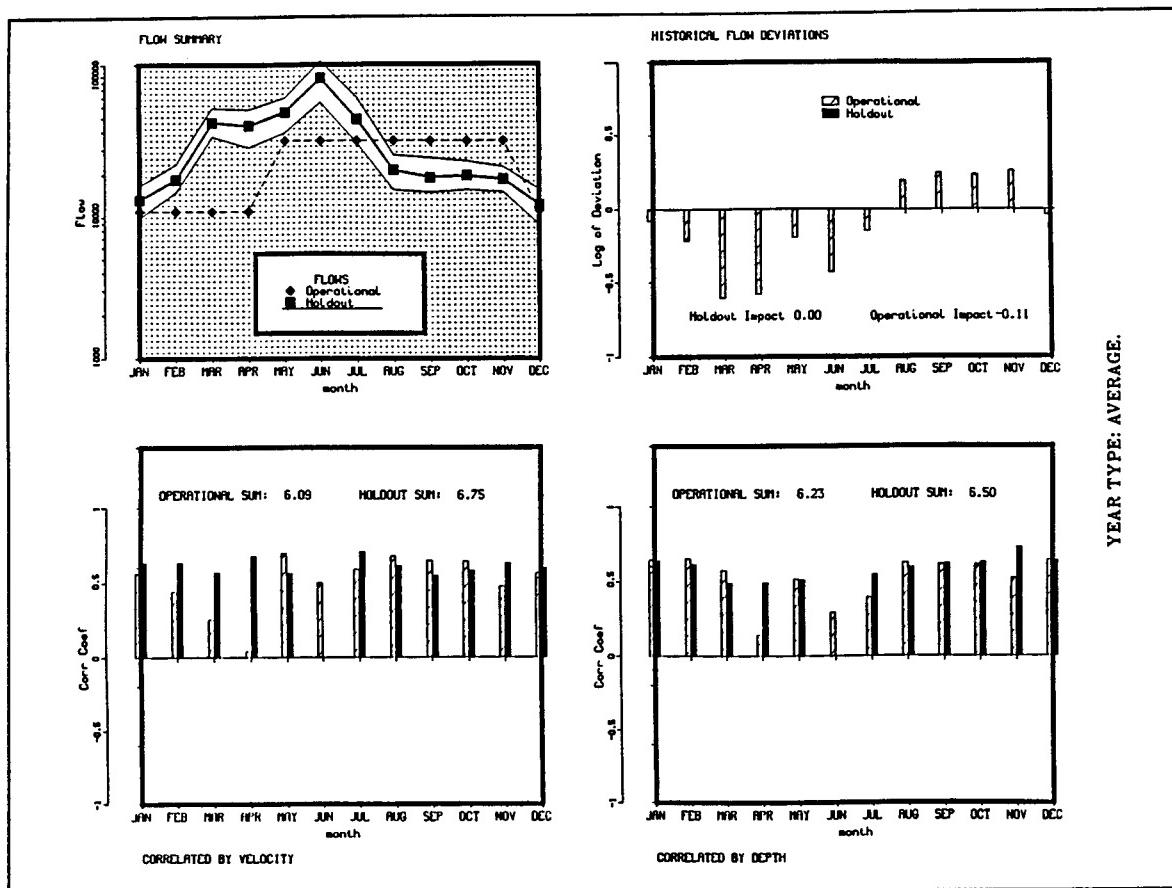
A similar pattern of disruption would occur for velocity distributions; that is, the discharge at which the velocity distribution between the project and CSRS channels occurs would be different (and also different from the discharges at which the depth distributions were similar). It is well-known that depth and velocity are correlated variables in rivers. It would appear that because of regulation the correlation between depth and velocity is different between the CSRS and the project channel. While these conclusions are speculative, they do point to a need to better understand how regulation may have affected the physical habitat features of warmwater fishes.

The change in the depth/velocity correlation between the project and the CSRS has a number of significant ramifications that deserve amplification. The alterations of the Missouri River from its preregulation conditions should be studied in much greater detail to better understand the effects of regulation and as a prelude for any restoration efforts on the Missouri River. The cycles of deposition and erosion are affected. In the CSRS channel, the low flow was more of an erosional feature than the project low-flow channel. Conversely, because the present high flows are inadequate to reach the overbank in most years, the present high flows that are relegated to the main channel are more erosional than the CSRS high flows (less conveyance at high flows in the project channel) and less likely to deposit organic matter than in the CSRS. Transport and storage of organic matter in streams is well known to affect the composition of the aquatic community.

Fish habitat is affected in several ways. First, because the correlation between depth and velocity has been altered by regulation, formulation of habitat suitability curves for detailed population studies must be done with considerable caution. The present habitat provided by the Gavins Point tailwater is considerably different than provided by the CSRS. Suitability curves developed in the present Missouri River may be misleading if the effects of channel alteration are not considered. Second, the availability of overbank areas or slower velocity areas is reduced at high flows. These effects are

probably life stage-specific and cannot be discussed in detail in this report. It is almost as though the habitat characteristics associated with high and low flow have been partially reversed; low flows in the project channel provide significant cross-sectional area and considerable opportunity for storage of organic matter. Missouri River in-channel hydraulic characteristics are now out of synchrony with the hydraulic patterns in the CSRS.

The results provided by the RCHARC analysis are summarized in Figure 20. Trends and patterns in the correlations can be easily observed. This can be important in exploring alternatives if a particular alternative provides good habitat (high correlation coefficients) for most months but very low habitat for one or more months. In Figure 20, the median monthly flow is presented as the holdout flow. Note that the median flow does not provide the maximum habitat value (maximum habitat value is 12) because of channel changes and distortions of the stage-discharge relationship.



**Figure 20.** Summary results for an application of the RCHARC to the Gavins Point tailwater. The upper left plot provides an estimate of the median, 25 percent exceedance flow, and 75 percent exceedance flow for the CSRS. An arbitrary annual flow sequence of monthly flows represents the project flows. The flows are presented on a log scale because the natural logarithm of discharge is linearly related to depth. The log scale gives an approximation of how depth could change as flows change. The upper right plot, the deviation plot, describes the degree to which the flows differ from the median. The lower two plots represent an annual time series of monthly correlation coefficients associated with the holdout (in this case, the median flow) and the operational flow. The sum of the holdout correlation coefficients represents the effects of the median CSRS hydrograph; the sum of the operational correlation coefficients represents the impacts of the project flow

## 5 Sources of Error and Uncertainty

---

As with any new methodology, RCHARC has produced the following suggestions for improving the approach, sources of error, and important caveats and assumptions:

- a. The discharges at which the CSRS cross sections were taken are unknown. The degree to which the cross sections may have changed at other discharges is unknown. Because the two calibration cross sections collected at each site for the project data differed little, this is not considered a major problem.
- b. It is not possible to determine the error in the velocity predictions. Although the cross sections are reasonably similar between the CSRS data set and the project channel, it was not learned that the slope of the stage-discharge relationship varies between CSRS and project channels until the study was almost complete. The differences in relative stage between the two data sets probably introduced a bias into the quadratic equation used for the velocity correction. Also, velocity is a derived variable (based on a calibration data set and not directly predicted like depth) in the project channel and a twice-derived variable in the CSRS. In the CSRS, velocities are first synthesized based on hydraulic radius and then adjusted with a correction factor.
- c. As with any method of smoothing, some loss of information occurs when curves are employed instead of original data. However, given the highly significant fits of the curves to the data, information loss associated with curve fitting is not considered to be a problem, and in fact, curve-fitted data probably more accurately capture trends and patterns of depth and velocity in the transects.
- d. Considerable problems were experienced in obtaining a consistent datum for the field data. Although good hydrologic practice was followed, it is possible that stage errors remain in the analysis.

- e. The method used to correct the velocity predictions for the CSRS channel will result in spurious self-correlation when the CSRS velocity distributions are compared to the project channels because a proportion of the distribution pattern in the project channel (that part represented by the quadratic equation) also occurs in the CSRS. Thus, the correlation coefficients at equivalent discharges will tend to be inflated. While the velocity correlations are useful and can provide insight into habitat conditions in the Missouri River, they should not receive the same credibility as the depth correlation coefficients unless sensitivity analyses are performed with both depth and velocity to determine if the pattern in the results is consistent between the two variables.
- f. Multiple sources of existing and newly collected hydraulic and hydrologic data were employed in this study. There was no opportunity to independently verify some of the data in this study, particularly for the CSRS channel.
- g. Impact will be expressed as a single number that integrates impact over a 93-year hydrologic record. However, there are many different patterns that will generate the same final estimate of total impact. The sequence of correlation coefficients should be evaluated to separate the alternatives that generate many years of average habitat from those alternatives that generate a mixture of extremely high and extremely low habitat values.

## 6 Discussion

---

The similarity results provided by the RCHARC analysis are shown in Appendix B. In the same manner as in the univariate analysis using correlations, the Canberra coefficients can be used to assess the various alternatives to distinguish the conditions most similar to historical hydraulic patterns based on median monthly flows. Seasonally dependent channel habitat conditions most like those of the preproject era can be approached on a species or life history-specific basis.

Tables of Canberra coefficients such as those in Appendix B give resource managers an opportunity to choose alternatives based on similarity matrices for a given water year (in this case a median year). However, from these numbers it is impossible to identify actual changes in depth-velocity profiles from historical to existing conditions. To allow for visual observation of hydraulic habitat alterations, contour plots (Figures 21 and 22) were generated that illustrate preproject and project depth-velocity relationships relative to total proportions.

Contour plots of two types were produced: (a) plotting depth versus velocity with the function variable percent of total frequency (per discharge) used as the contouring parameter (for historical and existing conditions, respectively); and (b) plotting depth versus velocity with the function variable percent frequency difference (the difference between historical and project frequency distributions) used as the contouring parameter. The latter plots present easily discernible information regarding loss and gain in hydraulic habitat from pre-project to project conditions. To compliment the habitat quality information, quantity was included in the form of top width within each plot.

Figure 21 depicts narrow channel plots for flows in a median winter month (10,000 cfs and 28,000 cfs) for preproject and project conditions, respectively. The contour plot of historic conditions reveals a diverse set of available habitat types including deep-slow and deep-fast, with higher proportions of habitat with moderate depth and slow-moving water. Examination of existing depth-velocity conditions indicates a more uniform and less diverse range of available habitats, yielding a direct relationship between the two variables (velocity increases with depth—a relationship not apparent in the former plot). Also note the complete absence of deep-slow water and the addition in high proportion of deeper-faster water areas. The bottom plot in Figure 21

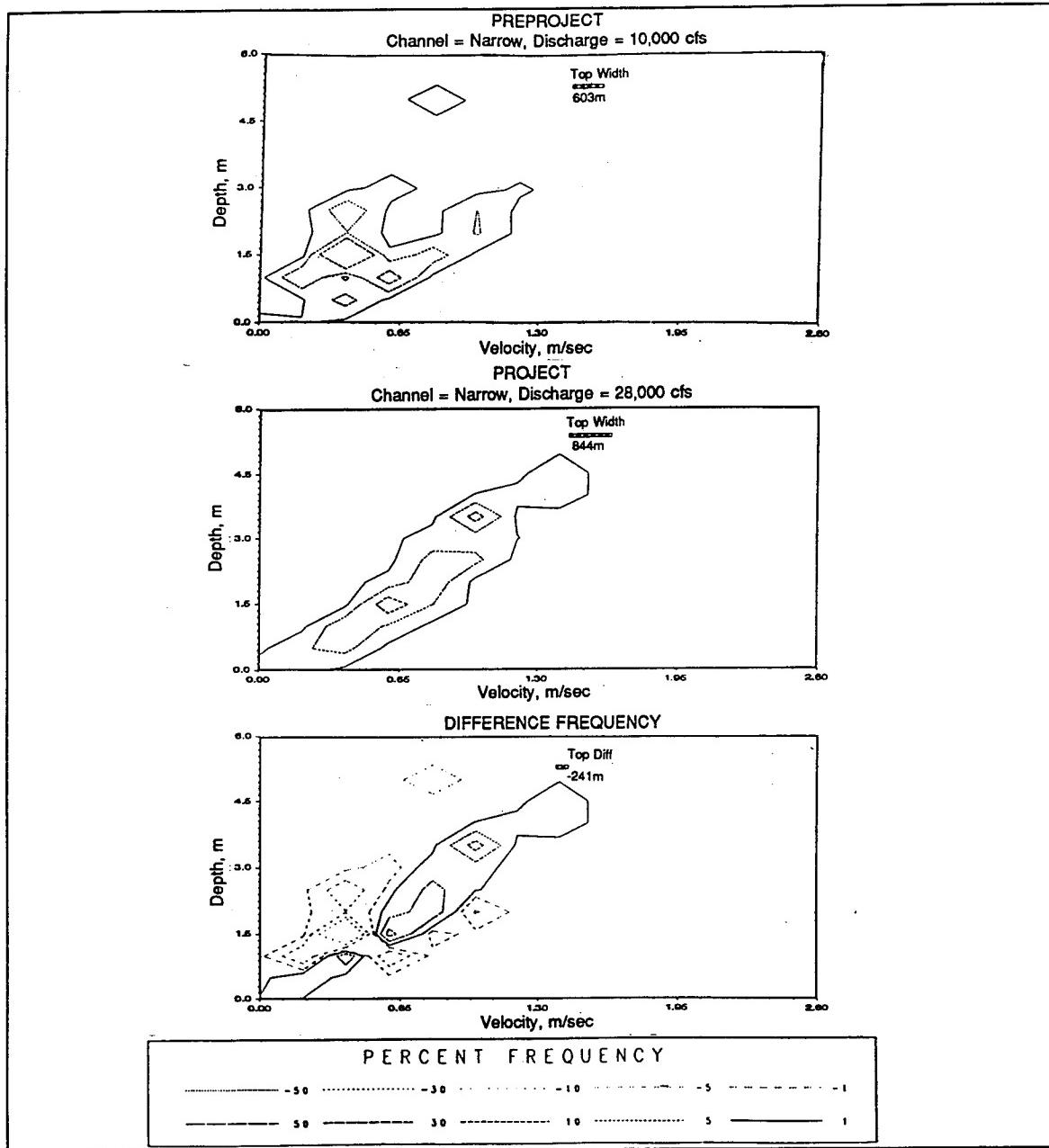


Figure 21. Bivariate contour plots for narrow channel. Top and middle plots relate depth and velocity (as a bivariable) to proportion of total frequency each depth-velocity increment represents. Upper plot presents historical conditions; middle plot presents existing conditions. Discharges modeled represent median winter monthly flows (10,000 cfs for preproject; 28,000 cfs for project). Note the more diverse habitat conditions available in historical plot and more uniform, direct depth-velocity relationship evident in project plot. Quantity of available habitat is included in these two plots in the form of top width. Bottom plot shows the differences in percent frequency between historical and existing depth-velocity conditions. Contour lines depict gains in habitat and lighter broken lines depict habitat loss. Top diff (preproject-project top width) signifies change in habitat quantity. Contour levels are shown in the legend

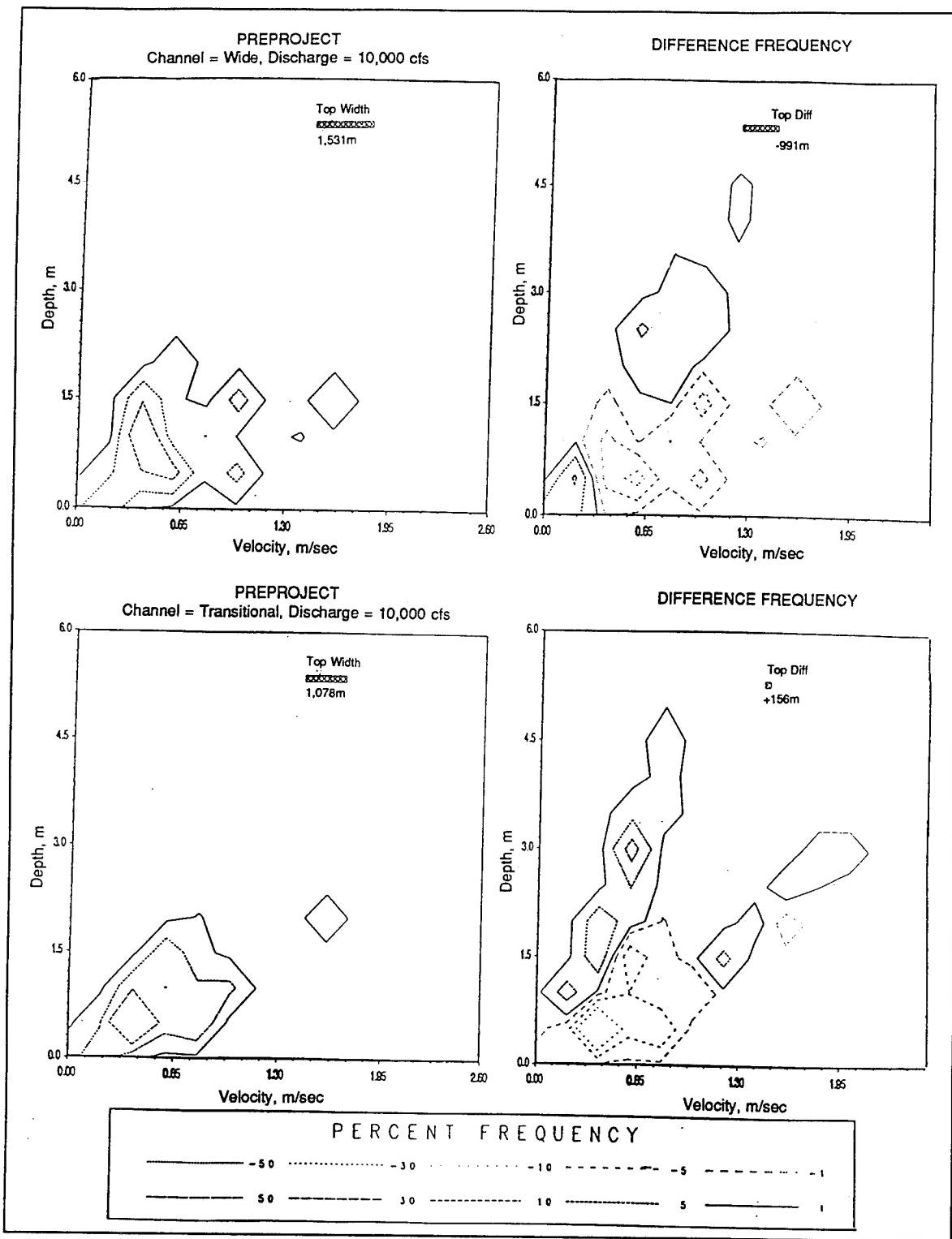


Figure 22. Preproject contour plots and difference in frequency plots for wide and transitional channels. Median monthly winter flows of 28,000 cfs were used in modeling project conditions for both channels. Note the almost complete loss of originally available habitat and general gain in habitats of greater depths in both frequency difference plots

illustrates the loss and gain of habitat type in a narrow channel for these particular flows.

Changes in depth-velocity relationships from preproject to project conditions for wide and transitional channels are shown in Figure 22. The project contour plots are omitted here, assuming the pertinent information can be gleaned from the difference in frequency plots. As in Figure 21, these contour plots represent historical flows of 10,000 cfs and existing flows of 28,000 cfs, and the top difference (diff) reflects the project top width subtracted from the preproject top width. Preproject conditions for the wide channel indicate habitats of mostly slow-moving shallow water with some swifter water at shallow and moderate depths. The difference in frequency plot for this channel reveals a loss of most of the originally available habitat and the addition of two previously unavailable habitat types: slow, shallow water and swift water at greater depths. For the transitional channel, preproject conditions show a dominance of shallow, mostly slow water for the median monthly winter flow. The difference in frequency plot for this channel indicates that with increased flows and a more narrow top width, habitats of swifter water with considerable depth gradients become available. The slow, shallow water apparent in the historical conditions is absent in the existing conditions.

## **7 Conclusions and Recommendations**

---

The study generated the following conclusions and recommendations:

- a.* The correlation coefficients generated for the Gavins Point tailwater could be interpreted and explained; in fact, correlation may be too sensitive a statistic for all applications of the RCHARC. The RCHARC provided insight to trends and patterns of physical habitat in this reach that could not have been determined in any other way. Based on the Gavins Point analysis, the RCHARC was able to summarize the effects of different operational alternatives on habitat for warmwater fishes, assuming that the CSRS represented the habitat ideal for this community.
- b.* Given the multiple uncertainties in the velocity data sets, use of the depth correlation coefficients as the basis of the impact assessment is suggested. The velocity correlation coefficients can be used if sensitivity analysis suggests that the two variables are providing much the same information.
- c.* Velocity distributions should be considered and discussed as information supplemental to the depth information.
- d.* The Gavins Point tailwater of the Missouri River is often presented as the last remaining “natural” reach in the system. This analysis has described a number of habitat alterations resulting from regulation in this reach. A truly “natural” segment of the lower Missouri River may no longer exist.
- e.* The RCHARC analysis both quantified and explained alterations in the Gavins Point reach of the river. An expansion of the RCHARC analysis would be valuable for restoration planning on the main stem Missouri River or any other large river considered for restoration.

- f. The RCHARC analysis was performed at an ecosystem level to describe major changes in the hydraulics and hydrology of the Gavins Point reach. The patterns and trends identified in this analysis should focus on future fishery and ecological investigations.
- g. The RCHARC analysis considered only physical habitat changes between the CSRS and the project channel. Clearly, habitat changes are a major feature of the impacts of different alternatives; however, because hydraulics affects everything else, other variables such as water temperature changes, water turbidity, and nutrient cycles should also be evaluated.
- h. Statistics other than the median could be used to summarize the long-term impact of each operational alternative. Possible options include minimum habitat analysis, increased weighting of key months, and the use of special rules (two sequential poor habitat years are emphasized).
- i. Like many analysis methodologies, the RCHARC can generate numbers and the numbers can be ranked, summed, and processed to support conclusions. However, it is critical that a RCHARC analysis be done at a level of rigor to understand differences in fluvial processes between the CSRS and the project alternatives that have ecological significance.
- j. Habitat for threatened and endangered species needs to be considered in light of RCHARC analysis first and then in context of standard habitat-based approaches. Development of habitat suitabilities for threatened and endangered species must acknowledge the major shifts in the depth and velocity patterns that have occurred in the Missouri River, even in the reach that is normally considered "natural." Certain critical habitat features may be much less abundant in the project river. It is, therefore, difficult to determine utilization that allows complete development of habitat suitability curves.
- k. The interpretation of the RCHARC analysis should also be performed using a bivariate approach for the Fort Randall, Garrison, and Fort Peck tailwaters to at least the rigor of the Gavins Point analysis to describe and understand the effects of river regulation on downstream habitat. The effects of river regulation on the warmwater fish community must be fully understood, particularly for threatened and endangered species whose decline has been associated with regulation.
- l. Bivariate contour plots based on proportional frequencies present easily discernible information regarding presence and absence of depth-velocity profiles through space (channel category) and time (monthly, yearly, or any other applicable time scale). These plots allow resource managers rapid visual assessment of available depth-velocity contours given particular objectives (i.e. recreational uses, fishery management) and flow alternatives.

- m.* The bivariate contour plots can also aid biologists and ecologists concerned with threatened and endangered species management, impact assessment and restoration, and community level management. Habitat preferences for endangered species, fish communities, or guilds (i.e. riffle dwellers) can be superimposed onto the contour plots to determine if habitat or life history requirements are achieved. The biologist can quickly peruse all possible flow alternatives and decide which flow condition produces the best patterns of habitat.

## References

---

- Bain, M. B., and Boltz, J. M. (1989). "Regulated streamflow and warmwater stream fish: A general hypothesis and research agenda," Biological Report 89(18), U.S. Fish and Wildlife Service, Washington, DC.
- Bain, M. B., Reed, M. S., and Scheidegger, K. J. (1991). "Fish community structure and microhabitat use in regulated and natural Alabama rivers," Prepared for Alabama Game and Fish Division, Department of Natural Resources, Montgomery, AL.
- Boesch, D. F. (1977). "Application of numerical classification in ecological investigations of water pollution," EPA-600/3-77-033, Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR.
- Bovee, K. D. (1986). "Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology," FWS/OBS-86/7, U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC.
- Clifford, H. T., and Stephenson, W. (1975). *An introduction to numerical classification*. Academic Press, New York.
- Gardner, W. M., and Stewart, P. A. (1987). "The fishes of the lower Missouri River, Montana," Federal Aid to Fish and Wildlife Restoration Project FW-2-R, Job I-b, Montana Department of Fish, Wildlife, and Parks, Helena, MT.
- Hesse, L. W., Schmulbach, J. C., Carr, J. M., Keenlyne, K. D., Unkenholtz, D. G., Robinson, J. W., and Mesti, G. E. (1989). "Missouri River fishery resources in relation to past, present, and future stresses." *Proceedings on the International Large River Symposium*. D. P. Dodge, ed., Publication of Canadian Journal of Fisheries and Aquatic Sciences.
- Hill, M. T., Platts, W. S., and Beschta, R. L. (1991). "Ecological and geomorphological concepts for instream and out-of-channel flow requirements," *Rivers* 2, 198-210.

- Hughes, N. F., and Dill, L. M. (1990). "Position choice by drift-feeding salmonids: Model and test for arctic grayling (*Thymallus arcticus*) in sub-arctic mountain streams, interior Alaska," *Canadian Journal Fisheries and Aquatic Science* 47, 2039-2048.
- Kallemeyn, L. W., and Novotny, J. F. (1977). "Fish and fish food organisms in various habitats of the Missouri River in South Dakota, Nebraska, and Iowa," U.S. Fish and Wildlife Service, Columbia, MO.
- Karr, J. R., Fausch, K. D., Angermeier, P. L., Yant, P. R., and Schlosser, I. J. (1986). "Assessing biological integrity in running waters; a method and its rationale," Illinois National History Survey Special Publication 5, Urbana, IL.
- Lance, G. N., and Williams, W. T. (1966). "A generalized sorting strategy for computer classifications," *Nature* 212:218.
- \_\_\_\_\_. (1967). "A general theory of classificatory sorting strategies. I. Hierarchical systems," *Computer Journal* 9, 373-380.
- Milhous, R. T., Updike, M., and Schneider, D. (1989). "Physical Habitat Simulation System Reference Manual - Version II," Biological Report 89(16), U.S. Fish and Wildlife Service, Washington, DC.
- Nestler, J. M. (1993). "Instream flow incremental methodology: A synopsis with recommendations for use and suggestions for future research," Technical Report EL-93-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Nestler, J. M., Schneider, L. T., and Hall, B. R. (1993). "Development of a simplified approach for assessing the effects of water release temperatures on tailwater habitat downstream of Fort Peck, Garrison, and Fort Randall Dams," Technical Report EL-93-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Pfleiger, W. L., and Grace, T. B. (1987). "Changes in the fish fauna of the Lower Missouri River, 1940-1983." *Community and evolutionary ecology of North American stream fishes*. W. J. Matthews and D. C. Heins, ed., University of Oklahoma Press, Norman, OK.
- Reiser, D. W., Wesche, T. A., and Estes, C. (1989). "Status of instream flow legislation and practices in North America," *Fisheries* 14(2), 22-29.
- SAS Institute, Inc. (1988). "SAS language guide for personal computers," Release 6.03 Edition, Cary, NC.
- Schmulbach, J. C. (1974). "An ecological study of the Missouri River prior to channelization," South Dakota Water Resources Project B-024-SDAK, Completion Report, South Dakota State University, Brookings, SD.

Tyus, H. M. (1992). "An instream flow philosophy for recovering endangered Colorado River fishes," *Rivers* 3, 27-36.

U.S. Army Engineer District, Omaha. (1989). "Investigations of channel degradation, 1989 update; Missouri River, Gavins Point Dam to Platte River confluence," Omaha, NE.

U.S. Army Engineer Division, Missouri River. (1992). "Modelling and hydrology technical report," Omaha, NE.

**Table 1**  
**Example of IFG4 Output Processed by the LSTVDX Program**

A1566.60	14000.0	1851.15		
B 2023.000	2000.000	0.00	0.00	90.00
B 2043.000	2023.000	0.00	0.00	90.00
B 2067.000	2043.000	2.65	1.01	90.00
B 2087.000	2067.000	9.15	2.31	90.00
B 2107.000	2087.000	7.65	2.05	90.00
B 2127.000	2107.00	10.35	2.51	90.00
B 2142.000	2127.00	14.85	3.19	90.00
B 2157.000	2142.00	18.05	3.64	90.00
B 2172.000	2157.00	17.15	3.52	90.00
B 2187.000	2172.00	17.65	3.58	90.00
B 2197.000	2187.00	18.55	3.71	90.00
B 2207.000	2197.00	19.25	3.80	90.00
B 2217.000	2207.00	17.85	3.61	90.00
B 2237.000	2217.00	12.75	2.88	90.00
B 2257.000	2237.000	8.65	2.22	90.00
B 2277.000	2257.000	8.15	2.14	90.00
B 2297.000	2277.000	6.65	1.86	90.00
B 2317.000	2297.000	8.75	2.24	90.00
B 2347.000	2317.000	8.15	2.14	90.00
B 2367.000	2347.000	7.05	1.94	90.00
B 2387.000	2367.000	7.65	2.05	90.00
B 2417.000	2387.000	6.85	1.90	90.00
B 2447.000	2417.000	6.25	1.79	90.00
B 2477.000	2447.000	6.85	1.90	90.00
B 2517.000	2477.000	4.85	1.51	90.00
B 2557.000	2517.000	4.35	1.40	90.00
B 2607.000	2557.000	2.55	0.98	90.00
B 2657.000	2607.000	0.35	0.26	90.00
B 2709.000	2657.000	0.00	0.00	90.00
B 2816.000	2709.000	0.00	0.00	90.00
B 2822.000	2816.000	0.00	0.00	90.00
B 2897.000	2822.000	0.85	0.47	90.00
B 2947.000	2897.000	2.65	1.01	90.00
B 2997.000	2947.000	3.15	1.13	90.00
B 3047.000	2997.000	2.65	1.01	90.00
B 3087.000	3047.000	3.55	1.22	90.00
B 3117.000	3087.000	5.35	1.61	90.00
B 3147.000	3117.000	7.15	1.96	90.00
B 3177.000	3147.000	8.55	2.21	90.00
B 3207.000	3177.000	5.05	1.55	90.00
B 3240.000	3207.000	0.00	0.00	90.00
B 3256.000	3240.000	0.00	0.00	90.00
B 3263.000	3256.000	0.00	0.00	90.00
B 3267.000	3263.000	0.00	0.00	90.00
B 3280.000	3267.000	0.00	0.00	90.00
B 3291.000	3280.000	0.00	0.00	90.00

**Note:**

Row A contains the river mile discharge, and water surface elevation. Row B contains the left and right bank adjacent cell boundaries, cell depth, cell velocity, and cell cover.

**Table 2**  
**Summary Statistics for Logistics Equation Fitted to the**  
**Logistics Equation for the Cumulative Depth Frequency**  
**Distribution**

----- CHANCATE=DIVIDED DISCHARGE=6000 -----

Source	DF	Sum of Squares	Mean Square
Regression	3	265388.36125	88462.78708
Residual	33	196.13955	5.94362
Uncorrected Total	36	265584.50080	
(Corrected Total)	35	16997.21240	

----- CHANCATE=DIVIDED DISCHARGE=8000 -----

Source	DF	Sum of Squares	Mean Square
Regression	3	276241.42995	92080.47665
Residual	35	143.39165	4.09690
Uncorrected Total	38	276384.82160	
(Corrected Total)	37	23361.04337	

----- CHANCATE=DIVIDED DISCHARGE=12000 -----

Source	DF	Sum of Squares	Mean Square
Regression	3	285582.97976	95194.32659
Residual	36	194.31627	5.39767
Uncorrected Total	39	285777.29603	
(Corrected Total)	38	24209.77055	

----- CHANCATE=DIVIDED DISCHARGE=14000 -----

Source	DF	Sum of Squares	Mean Square
Regression	3	284169.10381	94723.03460
Residual	36	204.11066	5.66974
Uncorrected Total	39	284373.21447	
(Corrected Total)	38	24725.08661	

----- CHANCATE=DIVIDED DISCHARGE=16000 -----

Source	DF	Sum of Squares	Mean Square
Regression	3	292358.03272	97452.67757
Residual	37	165.26034	4.46650
Uncorrected Total	40	292523.29306	
(Corrected Total)	39	26056.44776	

----- CHANCATE=DIVIDED DISCHARGE=20000 -----

Source	DF	Sum of Squares	Mean Square
Regression	3	236273.03927	78757.67976
Residual	32	353.54431	11.04826
Uncorrected Total	35	236626.58358	
(Corrected Total)	34	25577.73558	

(Sheet 1 of 8)

Note:

Note that the F-statistic (obtained by dividing the Mean Square Error of the Regression by the Mean Square of the Residuals) varies between 800 and 10,000. This range of F-values for linear regression would be highly significant.

**Table 2 (Continued)**

CHANCATE=WIDE DISCHARGE=24000			
Source	DF	Sum of Squares	Mean Square
Regression	3	250844.80073	83614.93358
Residual	35	186.37862	5.32510
Uncorrected Total	38	251031.17935	
(Corrected Total)	37	25351.37738	
CHANCATE=WIDE DISCHARGE=28000			
Source	DF	Sum of Squares	Mean Square
Regression	3	264462.24240	88154.08080
Residual	36	332.70368	9.24177
Uncorrected Total	39	264794.94608	
(Corrected Total)	38	23525.46113	
CHANCATE=WIDE DISCHARGE=32000			
Source	DF	Sum of Squares	Mean Square
Regression	3	272801.66684	90933.88895
Residual	37	462.43630	12.49828
Uncorrected Total	40	273264.10314	
(Corrected Total)	39	25365.87897	
CHANCATE=WIDE DISCHARGE=36000			
Source	DF	Sum of Squares	Mean Square
Regression	3	298889.60924	99629.86974
Residual	39	502.76844	12.89150
Uncorrected Total	42	299392.37768	
(Corrected Total)	41	24277.68115	
CHANCATE=WIDE DISCHARGE=40000			
Source	DF	Sum of Squares	Mean Square
Regression	3	301489.90375	100496.63458
Residual	40	472.75769	11.81894
Uncorrected Total	43	301962.66144	
(Corrected Total)	42	28722.56358	
CHANCATE=WIDE DISCHARGE=46000			
Source	DF	Sum of Squares	Mean Square
Regression	3	314097.73009	104699.24366
Residual	42	346.39820	8.24758
Uncorrected Total	45	314444.12829	
(Corrected Total)	44	32042.78763	
CHANCATE=WIDE DISCHARGE=50000			
Source	DF	Sum of Squares	Mean Square
Regression	3	309407.11366	103135.70455
Residual	42	341.75651	8.13706
Uncorrected Total	45	309748.87017	
(Corrected Total)	44	34715.36237	

**Table 2 (Continued)**

CHANCATE=WIDE DISCHARGE=6000			
Source	DF	Sum of Squares	Mean Square
Regression	3	164914.15726	54971.38575
Residual	21	201.62280	9.60109
Uncorrected Total	24	165115.78006	
(Corrected Total)	23	17778.79290	
CHANCATE=WIDE DISCHARGE=8000			
Source	DF	Sum of Squares	Mean Square
Regression	3	157294.08089	52431.36030
Residual	21	273.01540	13.00073
Uncorrected Total	24	157567.09629	
(Corrected Total)	23	20932.23726	
CHANCATE=WIDE DISCHARGE=10000			
Source	DF	Sum of Squares	Mean Square
Regression	3	158604.68939	52868.22980
Residual	22	238.49590	10.84072
Uncorrected Total	25	158843.18259	
(Corrected Total)	24	24254.28964	
CHANCATE=WIDE DISCHARGE=12000			
Source	DF	Sum of Squares	Mean Square
Regression	3	163919.29259	54639.76420
Residual	23	180.74781	7.85860
Uncorrected Total	26	164100.04040	
(Corrected Total)	25	25496.61848	
CHANCATE=WIDE DISCHARGE=14000			
Source	DF	Sum of Squares	Mean Square
Regression	3	158572.55655	52857.51885
Residual	23	172.33217	7.49270
Uncorrected Total	26	158744.88872	
(Corrected Total)	25	26458.21832	
CHANCATE=WIDE DISCHARGE=16000			
Source	DF	Sum of Squares	Mean Square
Regression	3	165361.09117	55120.36372
Residual	24	128.65409	5.36059
Uncorrected Total	27	165489.74526	
(Corrected Total)	26	27189.91800	
CHANCATE=WIDE DISCHARGE=20000			
Source	DF	Sum of Squares	Mean Square
Regression	3	235232.07482	78410.69161
Residual	34	180.30950	5.30322
Uncorrected Total	37	235412.38432	
(Corrected Total)	36	30957.34345	

**Table 2 (Continued)**

CHANCATE=TRANSIT DISCHARGE=24000			
Source	DF	Sum of Squares	Mean Square
Regression	3	148884.19251	49628.06417
Residual	29	188.95754	6.51578
Uncorrected Total	32	265584.50080	
(Corrected Total)	31	16997.21240	
CHANCATE=TRANSIT DISCHARGE=28000			
Source	DF	Sum of Squares	Mean Square
Regression	3	146261.03154	48753.67718
Residual	29	193.96908	6.68859
Uncorrected Total	32	146455.00061	
(Corrected Total)	31	36668.21689	
CHANCATE=TRANSIT DISCHARGE=32000			
Source	DF	Sum of Squares	Mean Square
Regression	3	153487.96026	51162.65342
Residual	30	164.71370	5.49046
Uncorrected Total	33	153652.67397	
(Corrected Total)	32	34855.71577	
CHANCATE=TRANSIT DISCHARGE=36000			
Source	DF	Sum of Squares	Mean Square
Regression	3	159722.41820	53240.80607
Residual	32	166.16008	5.19250
Uncorrected Total	35	159888.57828	
(Corrected Total)	34	37650.67619	
CHANCATE=TRANSIT DISCHARGE=40000			
Source	DF	Sum of Squares	Mean Square
Regression	3	164031.54347	54677.18116
Residual	33	205.89148	6.23914
Uncorrected Total	36	164237.43495	
(Corrected Total)	35	36855.30653	
CHANCATE=TRANSIT DISCHARGE=46000			
Source	DF	Sum of Squares	Mean Square
Regression	3	173455.48732	57818.49577
Residual	35	172.68530	4.93387
Uncorrected Total	38	173628.17261	
(Corrected Total)	37	37634.01262	
CHANCATE=TRANSIT DISCHARGE=50000			
Source	DF	Sum of Squares	Mean Square
Regression	3	176623.94008	58874.64669
Residual	36	198.76118	5.52114
Uncorrected Total	39	176822.70126	
(Corrected Total)	38	38524.19515	

**Table 2 (Continued)**

CHANCATE=DIVIDED DISCHARGE=24000			
Source	DF	Sum of Squares	Mean Square
Regression	3	247519.30844	82506.43615
Residual	34	244.80791	7.20023
Uncorrected Total	37	247764.11636	
(Corrected Total)	36	30334.70309	

CHANCATE=DIVIDED DISCHARGE=28000			
Source	DF	Sum of Squares	Mean Square
Regression	3	245734.08387	81911.36129
Residual	34	218.67071	6.43149
Uncorrected Total	37	245952.75458	
(Corrected Total)	36	30077.09131	

CHANCATE=DIVIDED DISCHARGE=32000			
Source	DF	Sum of Squares	Mean Square
Regression	3	256871.73201	85623.91067
Residual	35	175.91347	5.02610
Uncorrected Total	38	257047.64548	
(Corrected Total)	37	29273.43862	

CHANCATE=DIVIDED DISCHARGE=36000			
Source	DF	Sum of Squares	Mean Square
Regression	3	260060.00144	86686.66715
Residual	36	170.70553	4.74182
Uncorrected Total	39	260230.70698	
(Corrected Total)	38	32843.17545	

CHANCATE=DIVIDED DISCHARGE=40000			
Source	DF	Sum of Squares	Mean Square
Regression	3	263398.33931	87799.44644
Residual	37	154.50805	4.17589
Uncorrected Total	40	263552.84736	
(Corrected Total)	39	35582.29413	

CHANCATE=DIVIDED DISCHARGE=46000			
Source	DF	Sum of Squares	Mean Square
Regression	3	256348.85239	85449.61746
Residual	37	141.02930	3.81160
Uncorrected Total	40	256489.88169	
(Corrected Total)	39	37989.78081	

CHANCATE=DIVIDED DISCHARGE=50000			
Source	DF	Sum of Squares	Mean Square
Regression	3	259684.67020	86561.55673
Residual	38	159.33291	4.19297
Uncorrected Total	41	259884.00311	
(Corrected Total)	40	41816.06876	

**Table 2 (Continued)**

CHANCATE=NARROW DISCHARGE=6000				
Source	DF	Sum of Squares	Mean Square	
Regression	3	180344.36916	60114.78972	
Residual	31	2398.68840	77.37705	
Uncorrected Total	34	182743.05756		
(Corrected Total)	33	47985.19447		
CHANCATE=NARROW DISCHARGE=8000				
Source	DF	Sum of Squares	Mean Square	
Regression	3	180029.60872	60009.86957	
Residual	32	2713.44884	84.79528	
Uncorrected Total	35	182743.05756		
(Corrected Total)	34	51835.41913		
CHANCATE=NARROW DISCHARGE=10000				
Source	D F	Sum of Squares	Mean Square	
Regression	3	176364.49118	58788.16373	
Residual	32	2819.36468	88.10515	
Uncorrected Total	35	179183.85586		
(Corrected Total)	34	52433.37459		
CHANCATE=NARROW DISCHARGE=12000				
Source	DF	Sum of Squares	Mean Square	
Regression	3	176940.38899	58980.12966	
Residual	33	3263.81681	98.90354	
Uncorrected Total	36	180204.20580		
(Corrected Total)	35	54348.19673		
CHANCATE=NARROW DISCHARGE=14000				
Source	DF	Sum of Squares	Mean Square	
Regression	3	176638.63821	58879.54607	
Residual	34	3565.56760	104.86964	
Uncorrected Total	37	180204.20580		
(Corrected Total)	36	57749.71049		
CHANCATE=NARROW DISCHARGE=16000				
Source	DF	Sum of Squares	Mean Square	
Regression	3	173915.71599	57971.90533	
Residual	34	3381.12676	99.44490	
Uncorrected Total	37	177296.84275		
(Corrected Total)	36	57900.14660		
CHANCATE=NARROW DISCHARGE=20000				
Source	DF	Sum of Squares	Mean Square	
Regression	3	134544.22265	44848.07422	
Residual	27	322.30776	11.93732	
Uncorrected Total	30	134866.53041		
(Corrected Total)	29	31305.30231		

**Table 2 (Continued)**

CHANCATE=NARROW DISCHARGE=24000			
Source	DF	Sum of Squares	Mean Square
Regression	3	139257.65773	46419.21924
Residual	28	238.66998	8.52393
Uncorrected Total	31	139496.32771	
(Corrected Total)	30	31392.26413	
CHANCATE=NARROW DISCHARGE=28000			
Source	DF	Sum of Squares	Mean Square
Regression	3	149427.90958	49809.30319
Residual	30	161.62847	5.38762
Uncorrected Total	33	149589.53804	
(Corrected Total)	32	34261.94473	
CHANCATE=NARROW DISCHARGE=32000			
Source	DF	Sum of Squares	Mean Square
Regression	3	145123.08041	48374.36014
Residual	31	157.55730	5.08249
Uncorrected Total	34	145280.63771	
(Corrected Total)	33	36702.77300	
CHANCATE=NARROW DISCHARGE=36000			
Source	DF	Sum of Squares	Mean Square
Regression	3	151618.34925	50539.44975
Residual	33	150.33897	4.55573
Uncorrected Total	36	151768.68823	
(Corrected Total)	35	41937.69929	
CHANCATE=NARROW DISCHARGE=40000			
Source	DF	Sum of Squares	Mean Square
Regression	3	163275.05655	54425.01885
Residual	36	142.43654	3.95657
Uncorrected Total	39	163417.49309	
(Corrected Total)	38	46660.14727	
CHANCATE=NARROW DISCHARGE=46000			
Source	DF	Sum of Squares	Mean Square
Regression	3	182259.00020	60753.00007
Residual	37	299.82518	8.10338
Uncorrected Total	40	182558.82538	
(Corrected Total)	39	37804.43083	
CHANCATE=NARROW DISCHARGE=50000			
Source	DF	Sum of Squares	Mean Square
Regression	3	183610.51235	61203.50412
Residual	38	371.07824	9.76522
Uncorrected Total	41	183981.59059	
(Corrected Total)	40	42019.87349	

**Table 2 (Concluded)**

CHANCATE=TRANSIT DISCHARGE=6000			
Source	DF	Sum of Squares	Mean Square
Regression	3	53013.350870	17671.116957
Residual	11	50.260730	4.569157
Uncorrected Total	14	53063.611601	
(Corrected Total)	13	14209.541080	

CHANCATE=TRANSIT DISCHARGE=8000			
Source	DF	Sum of Squares	Mean Square
Regression	3	56844.156635	18948.052212
Residual	12	52.122412	4.343534
Uncorrected Total	15	56896.279047	
(Corrected Total)	14	15245.577630	

CHANCATE=TRANSIT DISCHARGE=10000			
Source	DF	Sum of Squares	Mean Square
Regression	3	60179.623312	20059.874437
Residual	13	63.876907	4.913608
Uncorrected Total	16	60243.500220	
(Corrected Total)	15	15652.239235	

CHANCATE=TRANSIT DISCHARGE=12000			
Source	DF	Sum of Squares	Mean Square
Regression	3	64816.485981	21605.495327
Residual	14	99.050356	7.075025
Uncorrected Total	17	64915.536336	
(Corrected Total)	16	15330.741086	

CHANCATE=TRANSIT DISCHARGE=14000			
Source	DF	Sum of Squares	Mean Square
Regression	3	69063.216803	23021.072268
Residual	15	183.892873	12.259525
Uncorrected Total	18	69247.109676	
(Corrected Total)	17	17359.067286	

CHANCATE=TRANSIT DISCHARGE=16000			
Source	DF	Sum of Squares	Mean Square
Regression	3	69874.573443	23291.524481
Residual	15	376.517068	25.101138
Uncorrected Total	18	70251.090511	
(Corrected Total)	17	14283.250243	

CHANCATE=TRANSIT DISCHARGE=20000			
Source	DF	Sum of Squares	Mean Square
Regression	3	147681.27493	49227.09164
Residual	28	157.82264	5.63652
Uncorrected Total	31	147839.09757	
(Corrected Total)	30	33046.05280	

**Table 3**  
**Canberra Coefficients for Gavins Point (Channel Categories Combined)**

<b>Q</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>Jun</b>	<b>Jul</b>	<b>Aug</b>	<b>Sep</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>
6,000	0.15989	0.13269	0.07905	0.08472	0.07823	0.07923	0.08680	0.12767	0.12987	0.12932	0.13269	0.16181
8,000	0.17538	0.16851	0.09699	0.10292	0.08996	0.08996	0.10095	0.15613	0.16408	0.16201	0.16861	0.17613
10,000	0.18351	0.17670	0.11860	0.12317	0.10938	0.10938	0.12215	0.16613	0.17368	0.17321	0.17570	0.18452
12,000	0.20706	0.20890	0.13407	0.13901	0.11903	0.11903	0.13841	0.19193	0.20487	0.20448	0.20890	0.21519
14,000	0.21710	0.21696	0.14195	0.14665	0.13263	0.13263	0.14027	0.20312	0.21223	0.20999	0.21696	0.21341
16,000	0.25022	0.24016	0.16361	0.16856	0.16003	0.16003	0.16023	0.23082	0.23795	0.23683	0.24016	0.24096
20,000	0.25212	0.28641	0.24275	0.26852	0.24407	0.24407	0.25701	0.27409	0.28537	0.29854	0.29504	0.25343
24,000	0.20815	0.24670	0.26668	0.26535	0.26715	0.26715	0.26734	0.26681	0.25308	0.25963	0.24670	0.20896
28,000	0.19024	0.21302	0.28326	0.29210	0.25432	0.25432	0.26972	0.23024	0.20987	0.21571	0.20392	0.18937
32,000	0.17158	0.19526	0.30445	0.31346	0.29860	0.29860	0.31196	0.22145	0.20018	0.20571	0.19526	0.16199
36,000	0.14023	0.16588	0.36602	0.37344	0.32994	0.32994	0.37201	0.19111	0.17132	0.17660	0.16588	0.13858
40,000	0.13443	0.15266	0.34396	0.36600	0.34265	0.34265	0.35088	0.18719	0.15992	0.16720	0.15288	0.13309
46,000	0.11434	0.12016	0.30758	0.31367	0.33046	0.33046	0.32340	0.14799	0.12690	0.13318	0.12016	0.10790
50,000	0.10731	0.10604	0.28619	0.29582	0.30636	0.30636	0.29488	0.13470	0.11109	0.11702	0.10604	0.10018

# **Appendix A**

## **Top Widths and Correlation Coefficients of the Gavins Point Tailwater**

---

Tables of coefficients are presented in two major groups. The first group contains the correlation coefficients for depth, and the second contains the correlations for velocity. Within each group, the tables occur in three major subsets, one subset for each of the types of water year (median flow, high flow, and low flow). Within each subset the coefficients are separated by channel category and then by top width adjustment. Within each pair of tables, the first table contains coefficients not adjusted for top width and the second member of the pair contains coefficients adjusted for top width.

GAVINS CHANNEL TOPWIDTHS BY DISCHARGE AND CHANNEL CATEGORY					
OBS	Q	DIVOTOP	NAROPTOP	TRAOPTOP	WIDOPTOP
1	6000	1237	1185	909	1939
2	8000	1237	1185	981	1974
3	10000	1391	1185	1055	2082
4	12000	1678	1204	1148	2107
5	14000	1678	1204	1192	2207
6	16000	1768	1204	1377	2275
7	20000	2056	1228	1425	2001
8	24000	2198	1322	1457	2397
9	28000	2294	1385	1513	2758
10	32000	2528	1428	1578	2956
11	36000	2638	1441	1672	3455
12	40000	2756	1496	1822	3549

COMBINED ADJUSTED COEFFICIENTS FOR DEPTH UNDER AVERAGE FLOWS

OBS	JA_IMPTD	FB_IMPTD	MA_IMPTD	AP_IMPTD	MY_IMPTD	JN_IMPTD	JL_IMPTD	AU_IMPTD	SP_IMPTD	OC_IMPTD	NO_IMPTD	DE_IMPTD
1	0.68443	0.655704	0.35854	0.37449	0.32762	0.30428	0.35226	0.59896	0.64631	0.63509	0.65704	0.69877
2	0.70013	0.69528	0.37700	0.39331	0.35006	0.32447	0.37235	0.63632	0.68440	0.67304	0.69528	0.70637
3	0.71393	0.73412	0.40499	0.42047	0.37908	0.35173	0.40080	0.67555	0.72822	0.71568	0.73412	0.71659
4	0.72845	0.76423	0.44092	0.45816	0.41182	0.38293	0.43574	0.71644	0.76635	0.75439	0.76423	0.72957
5	0.71232	0.75816	0.47578	0.49246	0.44639	0.41610	0.47085	0.74417	0.77132	0.76380	0.75816	0.70837
6	0.71988	0.77414	0.50506	0.52352	0.47130	0.44038	0.49847	0.78087	0.77795	0.78067	0.77414	0.71772
7	0.74625	0.77787	0.49564	0.51498	0.45224	0.42805	0.48639	0.73392	0.77085	0.76151	0.77787	0.73857
8	0.44087	0.68941	0.51281	0.53868	0.46244	0.44069	0.50432	0.72683	0.69773	0.70511	0.68941	0.63511
9	0.59716	0.64020	0.55028	0.57868	0.49612	0.47289	0.53771	0.67500	0.64800	0.65488	0.64020	0.59038
10	0.58316	0.62895	0.60351	0.63197	0.55015	0.52292	0.59121	0.66134	0.63631	0.64270	0.62895	0.57717
11	0.54851	0.59419	0.66386	0.69481	0.61604	0.58200	0.65116	0.62647	0.60162	0.60804	0.59419	0.53969
12	0.53321	0.58628	0.70471	0.73101	0.67185	0.63571	0.65928	0.61781	0.59351	0.59372	0.58628	0.52000
13	0.49151	0.54446	0.63007	0.64846	0.62199	0.58950	0.63369	0.56409	0.54937	0.5524	0.54446	0.48232
14	0.48083	0.54581	0.63639	0.65097	0.64768	0.61476	0.64271	0.56435	0.55052	0.55417	0.54581	0.46448
15	0.48083	0.54581	0.63639	0.65097	0.64768	0.61476	0.64271	0.56435	0.55052	0.55417	0.54581	0.46448

COMBINED ADJUSTED COEFFICIENTS FOR VELOCITY FOR AVERAGE YEAR

OBS	JA_IMPTV	FB_IMPTV	MA_IMPTV	AP_IMPTV	MY_IMPTV	JN_IMPTV	JL_IMPTV	AU_IMPTV	SP_IMPTV	OC_IMPTV	NO_IMPTV	DE_IMPTV
1	0.44802	0.43874	0.28714	0.29619	0.28030	0.27584	0.28474	0.41329	0.43487	0.43022	0.43874	0.48074
2	0.52021	0.49832	0.30851	0.32053	0.29607	0.29149	0.30431	0.47059	0.49365	0.48815	0.49832	0.56183
3	0.60261	0.5383	0.34071	0.35495	0.32675	0.32243	0.33603	0.55366	0.58332	0.57665	0.58383	0.64414
4	0.67548	0.65347	0.35798	0.37744	0.34500	0.34087	0.35454	0.61225	0.65660	0.64643	0.65347	0.70492
5	0.69512	0.67624	0.37804	0.40052	0.36080	0.35582	0.37264	0.66099	0.67909	0.68134	0.67624	0.72191
6	0.73064	0.72393	0.40759	0.43914	0.38762	0.38058	0.40364	0.71548	0.72393	0.72362	0.72393	0.74322
7	0.72686	0.77617	0.52476	0.56272	0.47821	0.45812	0.51428	0.75528	0.77551	0.77617	0.72625	
8	0.63050	0.69433	0.58784	0.61700	0.55015	0.53105	0.57998	0.70713	0.71979	0.69433	0.63106	
9	0.58219	0.62932	0.64650	0.67181	0.60695	0.58812	0.63773	0.68902	0.64118	0.65361	0.62932	0.58139
10	0.55960	0.59944	0.63943	0.71330	0.64458	0.62474	0.67890	0.65829	0.61133	0.62324	0.59944	0.55452
11	0.52202	0.55568	0.76218	0.77947	0.71889	0.69906	0.75220	0.61332	0.56701	0.57846	0.55568	0.51533
12	0.52027	0.54507	0.78453	0.79743	0.74460	0.72574	0.77544	0.60010	0.55550	0.56682	0.54507	0.50894
13	0.46924	0.49503	0.73891	0.73637	0.74864	0.73886	0.74743	0.52894	0.50926	0.49503	0.45830	
14	0.44915	0.48378	0.72415	0.71923	0.75303	0.74860	0.73455	0.51550	0.49661	0.49719	0.48378	0.43817
15	0.44915	0.48378	0.72415	0.71923	0.75303	0.74860	0.73455	0.51550	0.49661	0.49719	0.48378	0.43817

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR DIVIDED CHANNEL CATEGORY - AVERAGE YEAR

OBS	NAME	JA_DDEPC	FB_DDEPC	MA_DDEPC	AP_DDEPC	MY_DDEPC	JN_DDEPC	JL_DDEPC	SP_DDEPC	OC_DDEPC	NO_DDEPC	DE_DDEPC
1	K06DDEPC	0.91321	0.69445	0.52803	0.54171	0.55244	0.53613	0.53858	0.60187	0.67728	0.65937	0.69445
2	K08DDEPC	0.91630	0.83009	0.31949	0.3972	0.35299	0.36290	0.33151	0.77157	0.81996	0.80599	0.83009
3	K10DDEPC	0.96052	0.86746	0.42994	0.49642	0.46197	0.46792	0.44165	0.80517	0.85662	0.84494	0.86746
4	K12DDEPC	0.98740	0.89383	0.53297	0.59253	0.56311	0.56611	0.54413	0.83047	0.88279	0.87090	0.89383
5	K14DDEPC	0.99381	0.9805	0.57294	0.63199	0.60225	0.60521	0.58378	0.84672	0.89741	0.88594	0.90805
6	K16DDEPC	0.98544	0.93999	0.52556	0.59166	0.55665	0.56565	0.53663	0.87719	0.92108	0.91132	0.92999
7	K20DDEPC	0.98117	0.94853	0.74498	0.79382	0.76924	0.77209	0.75378	0.86598	0.90484	0.89970	0.91853
8	K24DDEPC	0.95162	0.98067	0.66101	0.74855	0.68874	0.70963	0.66985	0.95595	0.97714	0.97293	0.98067
9	K28DDEPC	0.94860	0.9278	0.69278	0.69689	0.77999	0.72333	0.74307	0.70531	0.94735	0.96906	0.96469
10	K32DDEPC	0.95893	0.95591	0.73328	0.80387	0.75836	0.77256	0.74159	0.92230	0.95056	0.94435	0.95591
11	K36DDEPC	0.91708	0.98563	0.64142	0.74179	0.66910	0.69774	0.64972	0.97452	0.98472	0.98319	0.98563
12	K40DDEPC	0.86305	0.97904	0.59369	0.70569	0.62176	0.65030	0.60137	0.98455	0.98132	0.98306	0.97904
13	K46DDEPC	0.79438	0.95436	0.54125	0.67052	0.56918	0.61729	0.54810	0.97622	0.95975	0.96470	0.95436
14	K50DDEPC	0.74310	0.92903	0.53321	0.66697	0.55944	0.61203	0.53914	0.96110	0.93633	0.94326	0.92903
15	KGTDDDEPC	0.74310	0.92903	0.53321	0.66697	0.55944	0.61203	0.53914	0.96110	0.93633	0.94326	0.70067

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL DEPTHS FOR DIVIDED CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_DDADJ	FB_DDADJ	MA_DDADJ	AP_DDADJ	MY_DDADJ	JN_DDADJ	JL_DDADJ	AU_DDADJ	SP_DDADJ	OC_DDADJ	NO_DDADJ	DE_DDADJ
1	0.60251	0.51257	0.28432	0.30460	0.25993	0.25513	0.27631	0.46564	0.50328	0.49393	0.51257	0.63783
2	0.60448	0.55360	0.24552	0.27536	0.22654	0.22636	0.23912	0.51496	0.54610	0.53846	0.55360	0.62208
3	0.69427	0.63523	0.29919	0.33246	0.27526	0.27415	0.29113	0.59006	0.62646	0.61753	0.63523	0.72368
4	0.84899	0.77712	0.38693	0.42881	0.35502	0.35284	0.37617	0.72178	0.76636	0.75543	0.77712	0.88731
5	0.85274	0.78296	0.39702	0.43739	0.36391	0.36165	0.38883	0.72819	0.77231	0.76150	0.78296	0.89057
6	0.89465	0.83444	0.40571	0.45115	0.37252	0.37163	0.39442	0.77990	0.82389	0.81314	0.83444	0.93005
7	0.94626	0.95396	0.53966	0.58972	0.49236	0.48918	0.52348	0.90153	0.95231	0.93985	0.95396	0.90169
8	0.87193	0.92123	0.54917	0.61385	0.50242	0.50453	0.53286	0.94672	0.92707	0.93256	0.92123	0.82284
9	0.83414	0.87916	0.58554	0.65218	0.53510	0.53687	0.56794	0.90311	0.88464	0.88980	0.87916	0.78881
10	0.76095	0.79096	0.65910	0.72875	0.60167	0.60164	0.63919	0.80897	0.79521	0.79916	0.79096	0.72156
11	0.71364	0.76950	0.65133	0.73368	0.59598	0.60132	0.63182	0.79630	0.77540	0.78105	0.76950	0.67120
12	0.66383	0.73411	0.66068	0.75258	0.60498	0.61436	0.64074	0.76608	0.74093	0.74756	0.73411	0.62136
13	0.63336	0.72495	0.53894	0.73534	0.58536	0.59845	0.61942	0.76286	0.73286	0.74064	0.72495	0.59562
14	0.62109	0.71556	0.63561	0.73377	0.58173	0.59650	0.61583	0.75703	0.72410	0.73256	0.72410	0.57743
15	0.62109	0.71556	0.63561	0.73377	0.58173	0.59650	0.61583	0.75703	0.72410	0.73256	0.71556	0.57743

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR NARROW CHANNEL CATEGORY - AVERAGE YEAR

OBS	_NAME_	JA_NDEPC	FB_NDEPC	MA_NDEPC	AP_NDEPC	MY_NDEPC	JN_NDEPC	JL_NDEPC	AU_NDEPC	SP_NDEPC	OC_NDEPC	NO_NDEPC	DE_NDEPC
1	K06NDEPC	0.91433	0.73000	-0.24400	-0.19768	-0.35710	-0.40431	-0.26917	0.56876	0.70378	0.67461	0.73000	0.92738
2	K08NDEPC	0.92683	0.83328	-0.15322	-0.09956	-0.27885	-0.33476	-0.18087	0.70691	0.81858	0.79579	0.83828	0.91432
3	K10NDEPC	0.93146	0.87813	-0.11892	-0.06121	-0.25476	-0.31581	-0.14889	0.76091	0.86130	0.84140	0.87813	0.91083
4	K12NDEPC	0.89435	0.94419	-0.0483	0.06133	-0.16301	-0.23584	-0.03988	0.87884	0.93658	0.92620	0.94419	0.85182
5	K14NDEPC	0.79985	0.95029	0.12139	0.19274	-0.05337	-0.13509	-0.08245	0.95328	0.95029	0.95328	0.95029	0.73882
6	K16NDEPC	0.76393	0.95304	0.20490	0.27999	0.01230	-0.07650	0.16182	0.9676	0.96039	0.96599	0.95304	0.69731
7	K20NDEPC	0.81775	0.76547	-0.01188	0.05627	-0.22714	-0.31994	-0.06002	0.70183	0.75620	0.74542	0.76547	0.81542
8	K24NDEPC	0.78280	0.74216	0.02027	0.08659	-0.19178	-0.28418	-0.02689	0.68766	0.73440	0.72528	0.74246	0.77899
9	K28NDEPC	0.76938	0.77008	0.12442	0.19161	-0.09367	-0.19135	-0.07658	0.73679	0.76616	0.76110	0.77008	0.75638
10	K32NDEPC	0.73481	0.80462	0.30163	0.36876	-0.07789	-0.02671	0.25370	0.80716	0.80896	0.80462	0.70659	
11	K36NDEPC	0.65884	0.80842	0.50641	0.57003	-0.28634	-0.17126	0.46066	0.85442	0.81863	0.82861	0.80842	0.61369
12	K40NDEPC	0.47615	0.69345	0.71558	0.76463	-0.53086	-0.43172	-0.67968	0.78834	0.71349	0.73204	0.69555	0.41905
13	K46NDEPC	0.46862	0.51725	0.28199	0.32553	0.12774	0.05070	0.25039	0.53112	0.52069	0.52395	0.51725	0.45259
14	K50NDEPC	0.46351	0.57100	0.44720	0.49124	0.28652	0.20237	0.41541	0.61355	0.57966	0.58843	0.57100	0.43369
15	KGTNDEPC	0.46351	0.57100	0.44720	0.49124	0.28652	0.20237	0.41541	0.61355	0.57966	0.58843	0.57100	0.43369

GAVINS TOPWIDTHII ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
OPERATIONAL DEPTHS FOR NARROW CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_NDADJ	FB_NDADJ	MA_NDADJ	AP_NDADJ	MY_NDADJ	JN_NDADJ	JL_NDADJ	AU_NDADJ	SP_NDADJ	OC_NDADJ	NO_NDADJ	DE_NDADJ
1	0.80693	0.73434	0.35216	0.37374	0.31386	0.29081	0.34568	0.66722	0.72393	0.71153	0.73434	0.80836
2	0.81220	0.78030	0.39445	0.41945	0.35205	0.32476	0.38744	0.72558	0.77271	0.76302	0.78030	0.80288
3	0.81415	0.79221	0.41043	0.43731	0.36382	0.33401	0.40257	0.74894	0.79086	0.78240	0.79721	0.80142
4	0.78590	0.81223	0.45626	0.48659	0.40216	0.36716	0.44697	0.78882	0.80986	0.80552	0.81223	0.76442
5	0.74670	0.81478	0.51413	0.54684	0.41557	0.50392	0.81074	0.81667	0.81683	0.81478	0.71777	
6	0.73180	0.81593	0.55241	0.58684	0.48639	0.44319	0.54087	0.82657	0.81981	0.82215	0.81593	0.70654
7	0.73939	0.72315	0.44417	0.47481	0.36109	0.32037	0.42904	0.69847	0.72007	0.71565	0.72315	0.7374
8	0.67361	0.66286	0.42601	0.45371	0.35367	0.31324	0.41258	0.64340	0.66057	0.65710	0.66286	0.66880
9	0.63812	0.643285	0.44814	0.47492	0.37857	0.33776	0.43568	0.63202	0.64207	0.64023	0.64285	0.63027
10	0.60682	0.63566	0.50315	0.52910	0.43667	0.39429	0.49208	0.63786	0.63719	0.63782	0.63566	0.59396
11	0.57501	0.62125	0.57706	0.60143	0.51611	0.47302	0.56815	0.64859	0.63545	0.63833	0.63125	0.55556
12	0.49287	0.57006	0.63302	0.65112	0.59198	0.55364	0.62932	0.60249	0.57670	0.58294	0.57006	0.47143
13	0.41680	0.43362	0.40208	0.41573	0.37068	0.34436	0.39821	0.43846	0.43504	0.43597	0.43362	0.41019
14	0.41535	0.44898	0.45389	0.46771	0.42287	0.39521	0.45076	0.46206	0.45191	0.45442	0.44898	0.4085
15	0.41535	0.44898	0.45389	0.46771	0.42287	0.39521	0.45076	0.46206	0.45191	0.45442	0.44898	0.4085

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL -  
OPERATIONAL DEPTHS FOR TRANSITIONAL CHANNEL CATEGORY - AVERAGE YEAR

OBS	_NAME_	JA_TDADJ	FB_TDADJ	MA_TDADJ	AP_TDADJ	MY_TDADJ	JN_TDADJ	JL_TDADJ	AU_TDADJ	SP_TDADJ	OC_TDADJ	NO_TDADJ	DE_TDADJ
1	K06TDADJ	0.82817	0.95228	0.75412	0.77359	0.53807	0.52785	0.68644	0.95562	0.95940	0.95228	0.79178	
2	K08TDADJ	0.73640	0.91339	0.80290	0.82234	0.60822	0.59436	0.74149	0.93589	0.91772	0.92309	0.91339	0.69797
3	K10TDADJ	0.66404	0.87604	0.79742	0.81785	0.61459	0.59915	0.73784	0.89624	0.87958	0.88444	0.87604	0.63193
4	K12TDADJ	0.56522	0.82351	0.76557	0.78834	0.60341	0.58744	0.70746	0.83043	0.82392	0.82611	0.82351	0.54976
5	K14TDADJ	0.57587	0.82261	0.83060	0.85028	0.68760	0.67177	0.78157	0.84132	0.82490	0.82947	0.82261	0.55316
6	K16TDADJ	0.53180	0.79572	0.72990	0.74655	0.57702	0.56599	0.66254	0.78710	0.79911	0.79671	0.79572	0.53861
7	K20TDADJ	0.56332	0.68200	0.96837	0.96247	0.95033	0.95029	0.96462	0.74694	0.70140	0.71298	0.68200	0.51921
8	K24TDADJ	0.48623	0.56167	0.95122	0.93770	0.97442	0.97484	0.96624	0.64734	0.58531	0.60079	0.56167	0.42796
9	K28TDADJ	0.45178	0.52587	0.93677	0.92157	0.97404	0.97574	0.95553	0.61218	0.54991	0.56540	0.52587	0.39413
10	K32TDADJ	0.45890	0.58389	0.92129	0.91143	0.94288	0.94617	0.92622	0.64670	0.60368	0.61449	0.58389	0.41958
11	K36TDADJ	0.35795	0.46203	0.86255	0.84684	0.92500	0.93093	0.88038	0.53072	0.48331	0.49506	0.46203	0.31600
12	K40TDADJ	0.31673	0.47411	0.79315	0.78362	0.84188	0.84856	0.79764	0.51688	0.49020	0.49688	0.47411	0.29413
13	K46TDADJ	0.26033	0.45138	0.69104	0.68658	0.72871	0.73563	0.68522	0.47135	0.46249	0.46479	0.45138	0.25419
14	K50TDADJ	0.21442	0.41268	0.63897	0.63522	0.68082	0.68797	0.63251	0.42669	0.42241	0.42355	0.41268	0.21254
15	KGTTDADJ	0.21442	0.41268	0.63897	0.63522	0.68082	0.68797	0.63251	0.42669	0.42241	0.42355	0.41268	0.21254

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
- OPERATIONAL DEPTHS FOR TRANSITIONAL CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_TDADJ	FB_TDADJ	MA_TDADJ	AP_TDADJ	MY_TDADJ	JN_TDADJ	JL_TDADJ	AU_TDADJ	SP_TDADJ	OC_TDADJ	NO_TDADJ	DE_TDADJ
1	0.454429	0.38109	0.26334	0.27134	0.23405	0.22956	0.25790	0.36108	0.37698	0.37306	0.38109	0.45268
2	0.465567	0.40308	0.29765	0.30086	0.26411	0.25552	0.28742	0.38362	0.39896	0.39515	0.40308	0.46295
3	0.47992	0.42502	0.31913	0.32276	0.28516	0.27886	0.30845	0.40411	0.42052	0.41642	0.42502	0.47851
4	0.49122	0.44954	0.34111	0.34555	0.30815	0.30122	0.32977	0.42447	0.44004	0.43910	0.44954	0.49448
5	0.51351	0.46654	0.36723	0.37118	0.33676	0.32338	0.35727	0.44336	0.46130	0.45677	0.46654	0.51455
6	0.57662	0.53099	0.39890	0.40475	0.36353	0.35612	0.38515	0.49709	0.52537	0.51821	0.53099	0.58885
7	0.60900	0.51470	0.47205	0.47064	0.46526	0.45937	0.47099	0.50285	0.51416	0.51128	0.51470	0.60169
8	0.59197	0.48861	0.47845	0.47513	0.48153	0.47559	0.48197	0.48483	0.48933	0.48853	0.48861	0.57825
9	0.60048	0.49576	0.49316	0.48929	0.49999	0.49410	0.49777	0.49272	0.49730	0.49609	0.49576	0.58625
10	0.62935	0.53672	0.51023	0.50761	0.51325	0.50761	0.51137	0.52490	0.53666	0.53363	0.53672	0.62259
11	0.62069	0.52494	0.52410	0.51968	0.53881	0.53364	0.52894	0.51699	0.52359	0.52359	0.52494	0.61155
12	0.65585	0.57676	0.54983	0.54691	0.56180	0.55668	0.55103	0.5528	0.55759	0.57125	0.57676	0.63889
13	0.59565	0.63309	0.55068	0.54923	0.55998	0.55511	0.54860	0.57511	0.60013	0.59368	0.60309	0.58302
14	0.55335	0.60885	0.55359	0.55232	0.56473	0.55996	0.55122	0.57840	0.60540	0.59843	0.60885	0.54344
15	0.55335	0.60885	0.55359	0.55232	0.56473	0.55996	0.55122	0.57840	0.60540	0.59843	0.60885	0.54344

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR WIDE CHANNEL CATEGORY - AVERAGE YEAR

OBS	_NAME_	JA_WDEPC	FB_WDEPC	MA_WDEPC	MY_WDEPC	AP_WDEPC	JN_WDEPC	JL_WDEPC	AU_WDEPC	SP_WDEPC	OC_WDEPC	NO_WDEPC	DE_WDEPC
1	X06WDEPC	0.73622	0.76339	0.69096	0.74230	0.67694	0.52938	0.70532	0.77287	0.76849	0.77214	0.76389	0.81049
2	X08WDEPC	0.81746	0.70887	0.73607	0.74734	0.58880	0.74057	0.79264	0.81565	0.81272	0.81746	0.90390	
3	X10WDEPC	0.84838	0.86445	0.73312	0.73747	0.80933	0.65223	0.77606	0.85764	0.84960	0.86445	0.96104	
4	X12WDEPC	0.94636	0.88800	0.76018	0.75979	0.83806	0.68820	0.80297	0.83729	0.88091	0.87256	0.88800	0.96964
5	X14WDEPC	0.96551	0.90357	0.77673	0.76337	0.86548	0.72447	0.82189	0.84620	0.89497	0.88511	0.90357	0.97563
6	X16WDEPC	0.96435	0.92365	0.81223	0.79944	0.89027	0.75825	0.85322	0.87424	0.91635	0.90779	0.92365	0.97157
7	X20WDEPC	0.97605	0.91592	0.94358	0.96269	0.91749	0.84427	0.94833	0.94738	0.92235	0.92791	0.91592	0.91722
8	X24WDEPC	0.54331	0.74413	0.80477	0.87168	0.68108	0.62791	0.77673	0.82668	0.76071	0.77683	0.74413	0.60004
9	X28WDEPC	0.48634	0.69333	0.74445	0.82223	0.60443	0.54528	0.71113	0.78137	0.71105	0.72868	0.69303	0.55180
10	X32WDEPC	0.58884	0.76513	0.79065	0.85916	0.85662	0.60597	0.76870	0.83600	0.87011	0.79452	0.76513	0.65049
11	X36WDEPC	0.65574	0.78077	0.75572	0.82242	0.67804	0.56860	0.74693	0.82906	0.79232	0.80316	0.78077	0.72497
12	X40WDEPC	0.82037	0.8737	0.81067	0.84833	0.80128	0.66934	0.82540	0.88615	0.88149	0.88461	0.87737	0.86989
13	X46WDEPC	0.88064	0.91542	0.84151	0.86185	0.86080	0.73066	0.86505	0.90857	0.91627	0.91602	0.91542	0.91420
14	X50WDEPC	0.93929	0.91532	0.81416	0.80781	0.88902	0.75301	0.85519	0.87616	0.90987	0.90320	0.91532	0.95230
15	XGTWDEPC	0.93929	0.91532	0.81416	0.80781	0.88902	0.75301	0.85519	0.87616	0.90987	0.90320	0.91532	0.95230

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
-OPERATIONAL DEPTHS FOR WIDE CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_WDADJ	FB_WDADJ	MA_WDADJ	AP_WDADJ	MY_WDADJ	JN_WDADJ	JL_WDADJ	AU_WDADJ	SP_WDADJ	OC_WDADJ	NO_WDADJ	DE_WDADJ
1	0.75753	0.82969	0.45614	0.47362	0.43164	0.38759	0.45358	0.74999	0.81364	0.79786	0.82969	0.78573
2	0.79216	0.87032	0.46930	0.48044	0.48240	0.40979	0.47131	0.77205	0.85042	0.83086	0.87032	0.81162
3	0.78413	0.92288	0.50200	0.50714	0.50007	0.44985	0.50724	0.82415	0.91769	0.89414	0.92288	0.79261
4	0.78150	0.92345	0.51596	0.51982	0.51411	0.46497	0.52111	0.84459	0.94034	0.91612	0.92345	0.78664
5	0.75343	0.88888	0.54553	0.54550	0.54654	0.49751	0.55156	0.88896	0.90466	0.91966	0.88888	0.75328
6	0.73048	0.87141	0.57357	0.57391	0.57087	0.52288	0.57834	0.93027	0.88752	0.90290	0.97141	0.72926
7	0.75935	0.93001	0.54106	0.55059	0.50935	0.48240	0.53479	0.85016	0.91271	0.89574	0.93001	0.76421
8	0.54470	0.74987	0.60184	0.62897	0.53492	0.51008	0.58420	0.87324	0.77394	0.79812	0.74987	0.56171
9	0.55593	0.63262	0.66934	0.70457	0.58742	0.55855	0.64737	0.74011	0.65366	0.67486	0.63262	0.47347
10	0.45472	0.61539	0.73639	0.77046	0.65949	0.62056	0.71718	0.71171	0.83449	0.65364	0.61539	0.46995
11	0.40543	0.53117	0.84391	0.88272	0.76963	0.70843	0.82793	0.60662	0.54658	0.56192	0.53117	0.42043
12	0.43394	0.54515	0.89400	0.91963	0.84863	0.77454	0.88866	0.60899	0.55857	0.57175	0.54515	0.44337
13	0.42954	0.53293	0.89341	0.85637	0.91496	0.83796	0.91767	0.59044	0.54509	0.55695	0.53293	0.43488
14	0.43449	0.52274	0.86336	0.85375	0.94213	0.86528	0.89542	0.56934	0.53292	0.54268	0.52274	0.43508
15	0.43449	0.52274	0.86336	0.85375	0.94213	0.86528	0.89542	0.56934	0.53292	0.54268	0.52274	0.43508

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR DIVIDED CHANNEL CATEGORY - AVERAGE YEAR

OBS	NAME	JA_DVEPC	FB_DVEPC	MA_DVEPC	AP_DVEPC	MY_DVEPC	JN_DVEPC	JL_DVEPC	AU_DVEPC	SP_DVEPC	OC_DVEPC	NO_DVEPC	DE_DVEPC
1	K06DVEPC	0.60099	0.35811	0.18585	0.19690	0.25295	0.22255	0.21085	0.29113	0.34559	0.33226	0.35811	0.56508
2	K08DVEPC	0.86105	0.69768	0.12235	0.18887	0.18032	0.19125	0.14191	0.63289	0.68600	0.67363	0.69768	0.83576
3	K10DVEPC	0.91346	0.33217	0.30115	0.38422	0.35171	0.37813	0.31608	0.79525	0.82636	0.81974	0.83217	0.91097
4	K12DVEPC	0.91860	0.82213	0.19144	0.27772	0.24087	0.26799	0.20685	0.77420	0.81348	0.80478	0.82138	0.90673
5	K14DVEPC	0.93666	0.90753	0.27290	0.37804	0.30655	0.35154	0.28148	0.88796	0.90525	0.90215	0.90753	0.94121
6	K16DVEPC	0.90475	0.85871	0.46490	0.56487	0.48197	0.52782	0.46658	0.90247	0.90088	0.90236	0.89871	0.91863
7	K20DVEPC	0.57760	0.65628	0.68231	0.76164	0.68417	0.73428	0.67768	0.75994	0.71002	0.72334	0.69628	0.62991
8	K24DVEPC	0.45503	0.57223	0.71749	0.73389	0.70680	0.75394	0.70866	0.85005	0.58838	0.60433	0.57223	0.51324
9	K28DVEPC	0.38830	0.44643	0.80617	0.84921	0.76454	0.82623	0.78724	0.52743	0.46257	0.47981	0.44643	0.44372
10	K32DVEPC	0.322385	0.36829	0.88598	0.90315	0.84229	0.86219	0.86759	0.43860	0.38219	0.39622	0.36829	0.34807
11	K36DVEPC	0.30110	0.36784	0.88585	0.90226	0.82963	0.84944	0.86326	0.43959	0.38195	0.39623	0.36784	0.322285
12	K40DVEPC	0.29250	0.36770	0.89059	0.90517	0.83157	0.84951	0.86722	0.43697	0.38131	0.3959	0.36770	0.31264
13	K46DVEPC	0.18845	0.28732	0.88002	0.88021	0.81521	0.82497	0.86708	0.33716	0.29686	0.30667	0.28732	0.20113
14	K50DVEPC	0.16787	0.27469	0.80997	0.81509	0.76107	0.77181	0.79503	0.32583	0.28443	0.29446	0.27469	0.17987
15	K57DVEPC	0.16787	0.27469	0.80997	0.81509	0.76107	0.77181	0.79503	0.32583	0.28443	0.29446	0.27469	0.17987

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL VELOCITIES FOR DIVIDED CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_DVADJ	FB_DVADJ	MA_DVADJ	AP_DVADJ	MY_DVADJ	JN_DVADJ	JL_DVADJ	AU_DVADJ	SP_DVADJ	OC_DVADJ	NO_DVADJ	DE_DVADJ
1	0.50418	0.41083	0.22065	0.23648	0.20979	0.20355	0.21746	0.37531	0.40370	0.39656	0.41083	0.51723
2	0.58608	0.51355	0.20984	0.23489	0.19763	0.19755	0.20507	0.47465	0.5050	0.49817	0.51355	0.60669
3	0.67760	0.62323	0.27225	0.30753	0.25550	0.25738	0.26578	0.56681	0.61625	0.60910	0.62323	0.71017
4	0.81961	0.74739	0.30073	0.34244	0.28183	0.28567	0.29400	0.69959	0.73815	0.72873	0.74739	0.85479
5	0.82732	0.78274	0.32129	0.36933	0.29675	0.30450	0.31218	0.7445	0.77550	0.76804	0.78274	0.87025
6	0.85733	0.82091	0.38958	0.44189	0.35665	0.36267	0.37644	0.79041	0.81522	0.80933	0.82091	0.90626
7	0.75350	0.84345	0.52028	0.57849	0.46669	0.47874	0.50077	0.85030	0.85283	0.85260	0.84345	0.74182
8	0.65006	0.73126	0.56785	0.62626	0.50779	0.51761	0.54524	0.79866	0.74478	0.75833	0.73126	0.64423
9	0.59429	0.64460	0.62325	0.67754	0.54790	0.55521	0.59523	0.7037	0.65709	0.65974	0.64460	0.58891
10	0.51425	0.55333	0.71717	0.76843	0.63039	0.63206	0.68543	0.60350	0.56350	0.57381	0.55333	0.48899
11	0.48434	0.53008	0.74833	0.80150	0.65330	0.65505	0.71360	0.58057	0.53991	0.54988	0.53008	0.46924
12	0.46053	0.50734	0.78377	0.83863	0.68324	0.68438	0.74710	0.55470	0.51655	0.52291	0.50734	0.44558
13	0.42346	0.47752	0.77938	0.82764	0.67774	0.67419	0.74705	0.51617	0.48497	0.49558	0.47752	0.40782
14	0.41613	0.47283	0.75034	0.79898	0.65564	0.65563	0.71822	0.51180	0.48032	0.48798	0.47283	0.40060
15	0.41613	0.47283	0.75034	0.79898	0.65564	0.65563	0.71822	0.51180	0.48032	0.48798	0.47283	0.40060

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL VELOCITIES FOR NARROW CHANNEL CATEGORY - AVERAGE YEAR

OBS	_NAME_	JA_NVEPC	FB_NVEPC	MA_NVEPC	AP_NVEPC	MY_NVEPC	JN_NVEPC	JL_NVEPC	AU_NVEPC	SP_NVEPC	OC_NVEPC	NO_NVEPC	DE_NVEPC
1	K06NVEPC	-0.15921	-0.20002	-0.23781	-0.25015	-0.24584	-0.24284	-0.24469	-0.22649	-0.20204	-0.20640	-0.20002	-0.11415
2	K08NVEPC	-0.01859	-0.11319	-0.26540	-0.27863	-0.27879	-0.27392	-0.27432	-0.18003	-0.18267	-0.18439	-0.18319	0.11953
3	K10NVEPC	0.34652	0.02893	-0.30033	-0.30489	-0.30665	-0.30550	-0.30701	0.03465	0.03225	0.03430	0.02833	0.50958
4	K12NVEPC	0.60055	0.25255	-0.30708	-0.29441	-0.29386	-0.29508	-0.30103	0.23232	0.25197	0.25160	0.25255	0.72606
5	K14NVEPC	0.76649	0.41630	-0.30662	-0.24523	-0.30813	-0.31095	-0.2987	0.39276	0.41323	0.41197	0.41630	0.36850
6	K16NVEPC	0.93271	0.63395	-0.24788	-0.13524	-0.27352	-0.29412	-0.24207	0.60173	0.63321	0.62666	0.64395	0.94623
7	K20NVEPC	0.64700	0.885067	0.45777	0.60600	0.24220	0.13922	0.41496	0.96959	0.89235	0.90978	0.88067	0.52578
8	K24NVEPC	0.45815	0.76554	0.71369	0.82266	0.52269	0.41817	0.67942	0.88553	0.77990	0.80122	0.76554	0.33752
9	K28NVEPC	0.28365	0.61153	0.87156	0.93937	0.71021	0.61052	0.84598	0.75700	0.62766	0.65159	0.61153	0.17422
10	K32NVEPC	0.22488	0.56661	0.89278	0.95318	0.72138	0.6128	0.86387	0.73159	0.58598	0.61329	0.56661	0.11776
11	K36NVEPC	0.08356	0.42788	0.94282	0.97504	0.78022	0.67331	0.91548	0.62205	0.45076	0.48214	0.42788	-0.00828
12	K40NVEPC	0.02026	0.34639	0.94735	0.96128	0.81833	0.72003	0.92900	0.53401	0.36644	0.39549	0.34639	-0.05858
13	K46NVEPC	0.03339	0.21247	0.86100	0.82422	0.95681	0.94188	0.90485	0.22237	0.20283	0.19888	0.21247	-0.02469
14	K50NVEPC	0.00063	0.15544	0.80396	0.75194	0.96088	0.96549	0.86395	0.14626	0.14347	0.13630	0.15544	-0.05131
15	KGTNVEPC	0.00063	0.15544	0.80396	0.75194	0.96088	0.96549	0.86395	0.14626	0.14347	0.13630	0.15544	-0.05131

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL VELOCITIES FOR NARROW CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_NVADJ	FB_NVADJ	MA_NVADJ	AP_NVADJ	MY_NVADJ	JN_NVADJ	JL_NVADJ	AU_NVADJ	SP_NVADJ	OC_NVADJ	NO_NVADJ	DE_NVADJ
1	0.35441	0.33957	0.35505	0.34930	0.36817	0.36964	0.35726	0.32899	0.33905	0.33720	0.33957	0.37154
2	0.41368	0.34671	0.34219	0.35603	0.35209	0.35300	0.34325	0.34874	0.34728	0.34655	0.34671	0.46954
3	0.56758	0.43675	0.32592	0.32280	0.33849	0.34002	0.32778	0.44005	0.43860	0.43947	0.43675	0.63313
4	0.66402	0.52328	0.31768	0.32037	0.32037	0.34062	0.32539	0.51594	0.52356	0.52340	0.52328	0.71250
5	0.73286	0.59169	0.31790	0.34604	0.33243	0.32915	0.32593	0.58302	0.59101	0.59047	0.59169	0.77130
6	0.80182	0.68880	0.34483	0.35647	0.34906	0.33916	0.35284	0.67049	0.68299	0.68680	0.80339	
7	0.66993	0.77034	0.65528	0.72192	0.58519	0.53620	0.64583	0.80841	0.77590	0.78304	0.77034	
8	0.55094	0.67176	0.71555	0.76105	0.66632	0.62058	0.71204	0.71899	0.67790	0.68602	0.67176	0.50283
9	0.46295	0.58327	0.74592	0.77295	0.71434	0.67270	0.74705	0.63937	0.59172	0.60042	0.55527	0.42136
10	0.42845	0.55182	0.73166	0.75501	0.69735	0.65558	0.73158	0.61115	0.55920	0.56883	0.55182	
11	0.37560	0.49842	0.74423	0.75657	0.71468	0.67417	0.74506	0.56732	0.50691	0.51788	0.49842	0.34205
12	0.34065	0.45270	0.71854	0.72368	0.70314	0.66861	0.72273	0.51681	0.46967	0.45270	0.31276	
13	0.29328	0.34652	0.58368	0.57214	0.64319	0.63828	0.60663	0.35016	0.34410	0.34298	0.34652	0.27541
14	0.28399	0.33022	0.56579	0.59497	0.64453	0.64604	0.59360	0.32825	0.32712	0.32507	0.33022	0.26790
15	0.28399	0.33022	0.56579	0.59497	0.64453	0.64604	0.59360	0.32825	0.32712	0.32507	0.33022	0.26790

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
VELOCITIES FOR TRANSITIONAL CHANNEL CATEGORY - AVERAGE YEAR

OBS	NAME	JA_TVADJ	FB_TVADJ	MA_TVADJ	AP_TVADJ	MY_TVADJ	JN_TVADJ	JL_TVADJ	AU_TVADJ	SP_TVADJ	OC_TVADJ	NO_TVADJ	DE_TVADJ
1	K06TVEPC	0.71051	0.73999	0.32143	0.39581	0.21484	0.17377	0.29183	0.76437	0.76531	0.78131	0.73909	0.79011
2	K08TVEPC	0.82962	0.85111	0.48069	0.54603	0.38364	0.3413	0.45415	0.84821	0.87311	0.88391	0.85111	0.88312
3	K10TVEPC	0.87307	0.91100	0.53872	0.59329	0.45647	0.42292	0.51634	0.84061	0.91945	0.91621	0.91100	0.89757
4	K12TVEPC	0.80967	0.91338	0.42883	0.46577	0.36997	0.34652	0.41283	0.66233	0.88303	0.84101	0.91338	0.78075
5	K14TVEPC	0.81582	0.91515	0.45761	0.49228	0.40430	0.38331	0.44318	0.66662	0.88501	0.84330	0.91515	0.78268
6	K16TVEPC	0.68545	0.83434	0.26436	0.29324	0.21774	0.19943	0.25161	0.47479	0.77903	0.71292	0.83434	0.62940
7	K20TVEPC	0.84674	0.77576	0.66148	0.70909	0.54049	0.49552	0.61469	0.94892	0.83261	0.87964	0.77576	0.92100
8	K24TVEPC	0.87832	0.78753	0.76135	0.81651	0.67758	0.63930	0.73938	0.97114	0.84594	0.89481	0.78753	0.93529
9	K28TVEPC	0.88500	0.77684	0.85720	0.90018	0.79182	0.76108	0.84032	0.96712	0.83550	0.88515	0.77684	0.92413
10	K32TVEPC	0.84902	0.72949	0.90730	0.93749	0.86363	0.84352	0.89625	0.92524	0.78745	0.83730	0.72949	0.87457
11	K36TVEPC	0.80601	0.67846	0.92581	0.95431	0.91045	0.89852	0.92979	0.87173	0.73402	0.78235	0.67846	0.81682
12	K40TVEPC	0.80516	0.67739	0.93828	0.95596	0.91383	0.90219	0.93253	0.87058	0.73287	0.78115	0.67739	0.81538
13	K46TVEPC	0.72149	0.58920	0.92705	0.93238	0.92503	0.92478	0.92732	0.78370	0.64234	0.68957	0.58920	0.72202
14	K50TVEPC	0.67222	0.53842	0.91101	0.91067	0.91955	0.92461	0.91413	0.73113	0.58973	0.63584	0.53842	0.66728
15	KGTVEPC	0.67222	0.53842	0.91101	0.91067	0.91955	0.92461	0.91413	0.73113	0.58973	0.63584	0.53842	0.66728

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR TRANSITIONAL CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_TVADJ	FB_TVADJ	MA_TVADJ	AP_TVADJ	MY_TVADJ	JN_TVADJ	JL_TVADJ	AU_TVADJ	SP_TVADJ	OC_TVADJ	NO_TVADJ	DE_TVADJ
1	0.42506	0.33947	0.20215	0.21353	0.18486	0.17636	0.19756	0.32397	0.34030	0.33915	0.33947	0.45225
2	0.49067	0.38996	0.24446	0.25524	0.22723	0.21795	0.23999	0.36624	0.38968	0.38710	0.38956	0.51344
3	0.54021	0.43294	0.27320	0.28289	0.25723	0.24813	0.26914	0.39225	0.42944	0.42344	0.43294	0.55640
4	0.56793	0.47169	0.27605	0.28338	0.26328	0.25550	0.27287	0.38549	0.45843	0.44268	0.47169	0.56818
5	0.59171	0.49022	0.29240	0.29936	0.28023	0.27255	0.28941	0.40115	0.47650	0.46022	0.49022	0.59059
6	0.63446	0.52421	0.29300	0.29969	0.28071	0.27299	0.28995	0.41022	0.51950	0.49404	0.54241	0.62359
7	0.71941	0.54339	0.39366	0.40987	0.36749	0.35225	0.38710	0.56100	0.55380	0.56103	0.54339	0.76082
8	0.74815	0.55928	0.43189	0.44542	0.40918	0.39474	0.42636	0.58013	0.57036	0.57825	0.55928	0.78369
9	0.77966	0.57730	0.47290	0.48384	0.45384	0.44042	0.46684	0.60120	0.58893	0.59742	0.57730	0.80912
10	0.79764	0.58606	0.50652	0.51453	0.49231	0.48084	0.50341	0.61368	0.59816	0.60727	0.58606	0.82214
11	0.82549	0.60285	0.54471	0.56992	0.53474	0.52468	0.54283	0.63217	0.61484	0.62220	0.60265	0.84428
12	0.89913	0.65629	0.59434	0.59976	0.58374	0.57286	0.59237	0.68846	0.66955	0.67974	0.65629	0.88623
13	0.91359	0.66035	0.62754	0.62928	0.62357	0.61561	0.62742	0.69719	0.67393	0.68478	0.66035	0.80050
14	0.76195	0.66304	0.64547	0.64536	0.64494	0.63846	0.64631	0.70182	0.67662	0.68767	0.66304	0.74724
15	0.76195	0.66304	0.64547	0.64536	0.64494	0.63846	0.64631	0.70182	0.67662	0.68767	0.66304	0.74724

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR WIDE CHANNEL CATEGORY - AVERAGE YEAR

OBS	_NAME_	JA_WVEPC	FB_WVEPC	MA_WVEPC	AP_WVEPC	MY_WVEPC	JN_WVEPC	JL_WVEPC	AU_WVEPC	SP_WVEPC	OC_WVEPC	NO_WVEPC	DE_WVEPC
1	K06WVEPC	0.20886	0.29669	0.14258	0.20202	0.13165	0.12328	0.14021	0.34303	0.30664	0.31625	0.29669	0.35221
2	K08WVEPC	0.42806	0.47542	0.31763	0.39419	0.26350	0.24969	0.30257	0.51596	0.48441	0.49286	0.47542	0.55235
3	K10WVEPC	0.58804	0.62805	0.47587	0.54989	0.42093	0.40744	0.46424	0.65977	0.63540	0.64225	0.62805	0.69468
4	K12WVEPC	0.73540	0.75234	0.61958	0.69007	0.54317	0.53006	0.59664	0.77695	0.75837	0.76384	0.75234	0.81622
5	K14WVEPC	0.75442	0.78708	0.65587	0.72065	0.59851	0.58805	0.64376	0.81110	0.79301	0.79337	0.78708	0.83618
6	K16WVEPC	0.81285	0.85137	0.73955	0.79037	0.68577	0.67736	0.72615	0.87262	0.85678	0.86160	0.85137	0.88507
7	K20WVEPC	0.83073	0.87120	0.76541	0.81224	0.71504	0.70742	0.75318	0.89112	0.87635	0.88090	0.87120	0.89931
8	K24WVEPC	0.75247	0.83721	0.74022	0.76215	0.73782	0.73461	0.74295	0.85702	0.84227	0.84676	0.83721	0.83494
9	K28WVEPC	0.81722	0.87042	0.76683	0.80955	0.72544	0.72281	0.76616	0.89184	0.87586	0.88071	0.87042	0.89017
10	K32WVEPC	0.89856	0.92938	0.84788	0.89000	0.79035	0.78204	0.83396	0.94698	0.93408	0.93818	0.92938	0.95000
11	K36WVEPC	0.93269	0.97471	0.93465	0.95033	0.90435	0.89833	0.92373	0.98360	0.97761	0.97593	0.97471	0.96409
12	K40WVEPC	0.92716	0.97569	0.97197	0.7169	0.94597	0.93758	0.96593	0.97824	0.97723	0.97724	0.97569	0.94797
13	K46WVEPC	0.85802	0.91125	0.94125	0.91782	0.95553	0.94749	0.95084	0.90756	0.91138	0.91105	0.91125	0.86357
14	K50WVEPC	0.82894	0.88029	0.92108	0.89325	0.94045	0.94048	0.93245	0.87423	0.87988	0.87905	0.88029	0.83085
15	KGTWVEPC	0.82894	0.88029	0.92108	0.89325	0.94045	0.94048	0.93245	0.87423	0.87988	0.87905	0.88029	0.83085

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR WIDE CHANNEL CATEGORY - AVERAGE YEAR

OBS	JA_WVADJ	FB_WVADJ	MA_WVADJ	AP_WVADJ	MY_WVADJ	JN_WVADJ	JL_WVADJ	AU_WVADJ	SP_WVADJ	OC_WVADJ	NO_WVADJ	DE_WVADJ
1	0.52743	0.60993	0.30822	0.32675	0.29129	0.28471	0.30327	0.56815	0.60116	0.59261	0.60993	0.58664
2	0.61203	0.70653	0.36185	0.38583	0.33110	0.32247	0.35271	0.65289	0.69527	0.68430	0.70653	0.66176
3	0.64528	0.80587	0.42864	0.45238	0.39272	0.38304	0.41818	0.75333	0.80790	0.79390	0.80587	0.68495
4	0.69680	0.85710	0.47474	0.49922	0.43163	0.42142	0.46205	0.81685	0.87908	0.86292	0.85710	0.72537
5	0.67251	0.83448	0.50965	0.53238	0.46833	0.45815	0.49764	0.87216	0.85599	0.87734	0.83448	0.70011
6	0.67414	0.83866	0.55057	0.57102	0.50911	0.49882	0.53868	0.92346	0.85994	0.88104	0.83866	0.69727
7	0.77401	0.90830	0.49146	0.50838	0.45557	0.44661	0.48122	0.82560	0.89087	0.87390	0.90830	0.79874
8	0.61852	0.79899	0.58032	0.59216	0.55298	0.54351	0.57309	0.88774	0.80979	0.82953	0.78989	0.64418
9	0.55742	0.69891	0.67869	0.69967	0.63319	0.62111	0.66591	0.78601	0.71663	0.73421	0.69891	0.57671
10	0.54336	0.67265	0.75992	0.78324	0.70255	0.68859	0.74365	0.7573	0.68938	0.70596	0.67265	0.55512
11	0.47324	0.58902	0.92991	0.94468	0.87343	0.85735	0.91457	0.65787	0.60309	0.61701	0.58902	0.47337
12	0.46178	0.57370	0.97364	0.98101	0.91680	0.89889	0.95902	0.63872	0.58700	0.60016	0.57370	0.46188
13	0.42437	0.53177	0.94180	0.92331	0.96139	0.94294	0.95988	0.59013	0.54370	0.55551	0.53177	0.42338
14	0.40977	0.51318	0.91424	0.89411	0.96778	0.95781	0.93270	0.56876	0.52455	0.53579	0.51318	0.40801
15	0.40977	0.51318	0.91424	0.89411	0.96778	0.95781	0.93270	0.56876	0.52455	0.53579	0.51318	0.40801

## COMBINED ADJUSTED COEFFICIENTS FOR DEPTH UNDER HIGH FLOW

OBS	JA_IMPTD	FB_IMPTD	MA_IMPTD	AP_IMPTD	MY_IMPTD	JN_IMPTD	JL_IMPTD	AU_IMPTD	SP_IMPTD	OC_IMPTD	NO_IMPTD	DE_IMPTD
1	0.69124	0.55862	0.30428	0.31272	0.30428	0.30428	0.30428	0.50508	0.52438	0.54195	0.57357	0.68873
2	0.71846	0.59430	0.32447	0.33378	0.32447	0.32447	0.32447	0.53793	0.55045	0.57691	0.60980	0.71439
3	0.73241	0.63021	0.35173	0.36179	0.35173	0.35173	0.35173	0.56984	0.59174	0.61152	0.64704	0.72854
4	0.75746	0.67306	0.38223	0.39364	0.38223	0.38223	0.38223	0.61413	0.63572	0.65502	0.68935	0.74991
5	0.74724	0.70408	0.41610	0.42739	0.41610	0.41610	0.41610	0.64890	0.66524	0.68730	0.71934	0.73736
6	0.76087	0.74145	0.44038	0.45197	0.44038	0.44038	0.44038	0.68676	0.70683	0.72480	0.75687	0.74948
7	0.77760	0.70171	0.42805	0.43731	0.42805	0.42805	0.42805	0.65885	0.67479	0.68890	0.71473	0.76643
8	0.67047	0.73568	0.44069	0.44903	0.44069	0.44069	0.44069	0.70127	0.71476	0.72652	0.74027	0.65986
9	0.62314	0.70044	0.47289	0.48177	0.47289	0.47289	0.47289	0.73267	0.7352	0.71239	0.68808	0.61374
10	0.61200	0.68552	0.52292	0.53336	0.52292	0.52292	0.52292	0.71642	0.70758	0.69681	0.67373	0.60222
11	0.57809	0.65085	0.58200	0.59493	0.58200	0.58200	0.58200	0.68229	0.67293	0.66177	0.63911	0.56889
12	0.56920	0.64213	0.63571	0.64963	0.63571	0.63571	0.63571	0.67511	0.66386	0.65319	0.63040	0.55896
13	0.53376	0.57959	0.58950	0.60222	0.58950	0.58950	0.58950	0.60206	0.59545	0.58734	0.57117	0.52730
14	0.53490	0.57893	0.61476	0.62831	0.61476	0.61476	0.61476	0.60030	0.59402	0.58627	0.57095	0.52805
15	0.53490	0.57893	0.61476	0.62831	0.61476	0.61476	0.61476	0.60030	0.59402	0.58627	0.57095	0.52805

## COMBINED ADJUSTED COEFFICIENTS FOR VELOCITY FOR HIGH FLOWS

OBS	JA_IMPTV	FB_IMPTV	MA_IMPTV	AP_IMPTV	MY_IMPTV	JN_IMPTV	JL_IMPTV	AU_IMPTV	SP_IMPTV	OC_IMPTV	NO_IMPTV	DE_IMPTV
1	0.45318	0.38845	0.27584	0.27747	0.27584	0.27584	0.27584	0.35843	0.36873	0.37872	0.39827	0.44643
2	0.51692	0.44487	0.29149	0.29315	0.29149	0.29149	0.29149	0.41169	0.42314	0.43416	0.45565	0.52033
3	0.59105	0.52305	0.32243	0.32402	0.32243	0.32243	0.32243	0.48284	0.49653	0.50986	0.56015	0.5338
4	0.66436	0.57595	0.34087	0.34240	0.34087	0.34087	0.34087	0.52996	0.54556	0.56080	0.59113	0.67376
5	0.68545	0.62380	0.35582	0.35762	0.35582	0.35582	0.35582	0.57531	0.59174	0.60779	0.63987	0.69384
6	0.73274	0.76777	0.38058	0.38312	0.38058	0.38058	0.38058	0.62673	0.64362	0.66017	0.69339	0.73965
7	0.76420	0.74179	0.45812	0.46531	0.45812	0.45812	0.45812	0.71224	0.72233	0.73201	0.75157	0.75020
8	0.66244	0.76664	0.53105	0.53809	0.53105	0.53105	0.53105	0.74120	0.74965	0.75847	0.77080	0.64795
9	0.60112	0.72126	0.58812	0.59522	0.58812	0.58812	0.58812	0.58812	0.58812	0.58812	0.73537	0.59015
10	0.57283	0.68999	0.62474	0.63225	0.62474	0.62474	0.62474	0.62474	0.62474	0.62474	0.71846	0.56307
11	0.53002	0.64372	0.69906	0.70664	0.69906	0.69906	0.69906	0.68488	0.67078	0.65705	0.63048	0.52083
12	0.52110	0.62726	0.72574	0.73305	0.72574	0.72574	0.72574	0.66731	0.65339	0.64001	0.61462	0.51341
13	0.47992	0.55711	0.73886	0.74317	0.73886	0.73886	0.73886	0.59336	0.58007	0.56806	0.54682	0.47643
14	0.47012	0.53355	0.74860	0.75167	0.74860	0.74860	0.74860	0.56649	0.55438	0.53306	0.46747	
15	0.47012	0.54355	0.74860	0.75167	0.74860	0.74860	0.74860	0.58000	0.56649	0.55438	0.53306	

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR DIVIDED CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	_NAME_	JA_DDEPC	FB_DDEPC	MA_DDEPC	AP_DDEPC	MY_DDEPC	JN_DDEPC	JL_DDEPC	AU_DDEPC	SP_DDEPC	OC_DDEPC	NO_DDEPC	DE_DDEPC
1	K06DDEPC	0.75984	0.55032	0.53613	0.54314	0.53613	0.53613	0.53613	0.48325	0.50632	0.52668	0.57126	0.80254
2	K08DDEPC	0.87891	0.72180	0.36290	0.36173	0.36290	0.36290	0.36290	0.65320	0.67707	0.63993	0.74267	0.91109
3	K10DDEPC	0.93355	0.75839	0.46792	0.46795	0.46792	0.46792	0.46792	0.69244	0.71555	0.73754	0.77815	0.94207
4	K12DDEPC	0.95521	0.78832	0.56611	0.56697	0.56611	0.56611	0.56611	0.72730	0.74888	0.76521	0.80624	0.95877
5	K14DDEPC	0.95449	0.80771	0.60321	0.60606	0.60521	0.60521	0.60521	0.75015	0.77063	0.78981	0.82438	0.96557
6	K16DDEPC	0.95288	0.83946	0.56556	0.56454	0.56556	0.56556	0.56556	0.78292	0.80311	0.82195	0.85570	0.98007
7	K20DDEPC	0.95919	0.84249	0.77509	0.77267	0.77269	0.77269	0.77269	0.80446	0.81133	0.85263	0.94510	
8	K24DDEPC	0.94158	0.70563	0.70460	0.70563	0.70563	0.70563	0.70563	0.91433	0.92484	0.93389	0.94798	0.97678
9	K28DDEPC	0.97594	0.93506	0.74307	0.73837	0.74307	0.74307	0.74307	0.91092	0.92036	0.92837	0.94051	0.96649
10	K32DDEPC	0.95185	0.90800	0.77256	0.76961	0.77256	0.77256	0.77256	0.88158	0.89176	0.90053	0.91426	0.95744
11	K36DDEPC	0.97790	0.96694	0.69774	0.69030	0.69774	0.69774	0.69774	0.94882	0.95625	0.96226	0.97041	0.96477
12	K40DDEPC	0.96006	0.98426	0.66530	0.64965	0.66030	0.66030	0.66030	0.97612	0.98016	0.98283	0.98456	0.93972
13	K46DDEPC	0.92453	0.98345	0.61299	0.60350	0.61279	0.61279	0.61279	0.98605	0.98638	0.98547	0.98044	0.89747
14	K50DDEPC	0.89088	0.97498	0.61033	0.59682	0.61203	0.61203	0.61203	0.98682	0.98397	0.97999	0.96907	0.85817
15	K57DDEPC	0.89088	0.97498	0.61203	0.59682	0.61203	0.61203	0.61203	0.98682	0.98397	0.97999	0.96907	0.85817

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL DEPTHS FOR DIVIDED CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	JA_DDADJ	FB_DDADJ	MA_DDADJ	AP_DDADJ	MY_DDADJ	JN_DDADJ	JL_DDADJ	AU_DDADJ	SP_DDADJ	OC_DDADJ	NO_DDADJ	DE_DDADJ
1	0.53804	0.43890	0.25513	0.25837	0.25513	0.25513	0.25513	0.40664	0.41736	0.42811	0.44971	0.55246
2	0.57445	0.45744	0.22636	0.22800	0.22636	0.22636	0.22636	0.45234	0.46467	0.47607	0.49877	0.5873
3	0.65787	0.55577	0.27415	0.27638	0.27415	0.27415	0.27415	0.52176	0.53451	0.54718	0.57228	0.66333
4	0.80259	0.68676	0.35284	0.35590	0.35284	0.35284	0.35284	0.64238	0.65732	0.67212	0.70127	0.81437
5	0.80686	0.69221	0.36165	0.36478	0.36165	0.36165	0.36165	0.65088	0.66550	0.67994	0.70831	0.81720
6	0.85773	0.74429	0.37163	0.37441	0.37163	0.37163	0.37163	0.69862	0.71406	0.72928	0.75911	0.86739
7	0.95403	0.86695	0.48918	0.49332	0.48918	0.48918	0.48918	0.88130	0.88225	0.88745	0.89547	
8	0.91259	0.96494	0.50453	0.50714	0.50453	0.50453	0.50453	0.93256	0.94766	0.96235	0.97045	
9	0.87038	0.92145	0.53687	0.53977	0.53687	0.53687	0.53687	0.93963	0.93433	0.92825	0.91400	0.86495
10	0.78497	0.82447	0.60164	0.60552	0.60164	0.60164	0.60164	0.83957	0.83522	0.83017	0.81818	0.78127
11	0.75839	0.81450	0.60132	0.60355	0.60132	0.60132	0.60132	0.83331	0.82768	0.82139	0.80706	0.75150
12	0.71937	0.78649	0.61436	0.61538	0.61436	0.61436	0.61436	0.80881	0.80192	0.79446	0.77805	0.71015
13	0.70634	0.78617	0.59845	0.59816	0.59845	0.59845	0.59845	0.81287	0.80444	0.79552	0.77644	0.69468
14	0.69399	0.78281	0.59650	0.59567	0.59650	0.59650	0.59650	0.81318	0.80347	0.79332	0.77198	0.68039
15	0.69399	0.78281	0.59650	0.59567	0.59650	0.59650	0.59650	0.81318	0.80347	0.79332	0.77198	0.68029

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR NARROW CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	NAME	JA_NDEPC	FB_NDEPC	MA_NDEPC	AP_NDEPC	MY_NDEPC	JN_NDEPC	JL_NDEPC	AU_NDEPC	SP_NDEPC	OC_NDEPC	NO_NDEPC	DE_NDEPC
1	K06NDEPC	0.81404	0.42644	-0.40431	-0.38854	-0.40431	-0.40431	0.21324	0.29606	0.36634	0.47832	0.85605	
2	K08NDEPC	0.89399	0.57618	-0.33476	-0.31596	-0.33476	-0.33476	0.36184	0.44761	0.51795	0.62488	0.91535	
3	K10NDEPC	0.92239	0.63722	-0.31581	-0.29521	-0.31581	-0.31581	0.42563	0.51146	0.58073	0.68379	0.93611	
4	K12NDEPC	0.95326	0.77953	-0.23584	-0.21109	-0.23584	-0.23584	0.59023	0.67037	0.73185	0.81690	0.94448	
5	K14NDEPC	0.92256	0.87959	-0.13509	-0.10712	-0.13509	-0.13509	0.73013	0.79741	0.84533	0.90405	0.89171	
6	K16NDEPC	0.90961	0.93292	-0.07760	-0.04667	-0.07760	-0.07760	0.81200	0.86903	0.90737	0.94955	0.87028	
7	K20NDEPC	0.79392	0.63202	-0.31994	-0.28779	-0.31994	-0.31994	0.50299	0.55686	0.59868	0.65926	0.80704	
8	K24NDEPC	0.76574	0.62579	-0.25210	-0.28418	-0.28418	-0.28418	0.50869	0.55788	0.59577	0.65018	0.77629	
9	K28NDEPC	0.77953	0.69019	-0.19135	-0.15727	-0.19135	-0.19135	0.59169	0.63418	0.66586	0.70936	0.78115	
10	K32NDEPC	0.79036	0.78708	-0.02671	0.01006	-0.02671	-0.02671	0.72179	0.75212	0.77275	0.79716	0.77703	
11	K36NDEPC	0.76630	0.86735	0.17826	0.21658	0.17826	0.17826	0.84607	0.85989	0.86595	0.86585	0.73562	
12	K40NDEPC	0.62660	0.84180	0.43172	0.46735	0.43172	0.43172	0.88247	0.87174	0.85750	0.82266	0.58056	
13	K46NDEPC	0.50410	0.52993	0.05070	0.07801	0.05070	0.05070	0.50734	0.51889	0.52581	0.52322	0.49490	
14	K50NDEPC	0.53828	0.63289	0.20237	0.23241	0.20237	0.20237	0.63542	0.63745	0.63640	0.62828	0.51640	
15	K56NDEPC	0.53828	0.63289	0.20237	0.23241	0.20237	0.20237	0.63542	0.63745	0.63640	0.62828	0.51640	

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
HISTORICAL/OPERATIONAL DEPTHS FOR NARROW CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	JA_NDADJ	FB_NDADJ	MA_NDADJ	AP_NDADJ	MY_NDADJ	JN_NDADJ	JL_NDADJ	AU_NDADJ	SP_NDADJ	OC_NDADJ	NO_NDADJ	DE_NDADJ
1	0.76924	0.61030	0.29081	0.29851	0.29081	0.29081	0.52523	0.55889	0.58689	0.63000	0.78706	
2	0.80315	0.67437	0.32476	0.33394	0.32476	0.32476	0.58956	0.62424	0.65202	0.69246	0.81221	
3	0.81519	0.70048	0.33401	0.34407	0.33401	0.33401	0.63401	0.61717	0.65178	0.67898	0.71756	0.82101
4	0.81521	0.74935	0.36716	0.37906	0.36716	0.36716	0.67757	0.70894	0.73215	0.76207	0.81154	
5	0.80240	0.79149	0.41557	0.42901	0.41557	0.41557	0.73718	0.76286	0.78013	0.79853	0.78952	
6	0.79699	0.81394	0.44319	0.4506	0.44319	0.44319	0.77206	0.79322	0.80635	0.81771	0.78058	
7	0.73408	0.67381	0.32037	0.33551	0.32037	0.32037	0.62037	0.62788	0.64785	0.66264	0.68235	
8	0.67117	0.62351	0.31324	0.32728	0.31324	0.31324	0.58544	0.60218	0.61441	0.63036	0.67518	
9	0.64564	0.61872	0.33776	0.35200	0.33776	0.33776	0.58956	0.60294	0.61222	0.62327	0.64623	
10	0.63001	0.63449	0.39429	0.40119	0.39429	0.39429	0.61854	0.62698	0.63388	0.63555	0.62332	
11	0.61594	0.65701	0.47302	0.48841	0.47302	0.47302	0.65720	0.65955	0.65910	0.65389	0.60324	
12	0.54637	0.62419	0.55364	0.56742	0.55364	0.55364	0.64553	0.63935	0.63200	0.61628	0.53390	
13	0.42944	0.44072	0.34536	0.35433	0.34536	0.34536	0.43955	0.44100	0.44127	0.43967	0.42281	
14	0.43920	0.47038	0.39521	0.40509	0.39521	0.39521	0.47669	0.47553	0.47325	0.46720	0.43295	
15	0.43920	0.47038	0.39521	0.40509	0.39521	0.39521	0.47669	0.47553	0.47325	0.46720	0.43295	

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
AND OPERATIONAL DEPTHS FOR TRANSITIONAL CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	_NAME_	JA_TDPC	FB_TDPC	FB_TDPC	MA_TDPC	MY_TDPC	AP_TDPC	AP_TDPC	JN_TDPC	JL_TDPC	AU_TDPC	SP_TDPC	OC_TDPC	NO_TDPC	DE_TDPC
1	K06TDPC	0.93556	0.96365	0.52785	0.53184	0.52785	0.52785	0.52785	0.52785	0.52785	0.52785	0.52785	0.52785	0.52785	0.52785
2	K08TDPC	0.88307	0.94295	0.59436	0.59953	0.59436	0.59436	0.59436	0.59436	0.59436	0.59436	0.59436	0.59436	0.59436	0.59436
3	K10TDPC	0.83792	0.90417	0.59915	0.60481	0.59915	0.59915	0.59915	0.59915	0.59915	0.59915	0.59915	0.59915	0.59915	0.59915
4	K12TDPC	0.77630	0.83198	0.58744	0.59321	0.58744	0.58744	0.58744	0.58744	0.58744	0.58744	0.58744	0.58744	0.58744	0.58744
5	K14TDPC	0.77483	0.85246	0.67177	0.67177	0.67177	0.67177	0.67177	0.67177	0.67177	0.67177	0.67177	0.67177	0.67177	0.67177
6	K16TDPC	0.75096	0.78023	0.56599	0.57006	0.56599	0.56599	0.56599	0.56599	0.56599	0.56599	0.56599	0.56599	0.56599	0.56599
7	K20TDPC	0.65222	0.79623	0.95029	0.95060	0.95029	0.95029	0.95029	0.95029	0.95029	0.95029	0.95029	0.95029	0.95029	0.95029
8	K24TDPC	0.53614	0.71364	0.97484	0.97489	0.97484	0.97484	0.97484	0.97484	0.97484	0.97484	0.97484	0.97484	0.97484	0.97484
9	K28TDPC	0.50012	0.67987	0.97574	0.97539	0.97574	0.97574	0.97574	0.97574	0.97574	0.97574	0.97574	0.97574	0.97574	0.97574
10	K32TDPC	0.52222	0.69723	0.94617	0.94527	0.94617	0.94617	0.94617	0.94617	0.94617	0.94617	0.94617	0.94617	0.94617	0.94617
11	K36TDPC	0.43265	0.58766	0.93093	0.92906	0.93093	0.93093	0.93093	0.93093	0.93093	0.93093	0.93093	0.93093	0.93093	0.93093
12	K40TDPC	0.43866	0.55512	0.84846	0.84633	0.84846	0.84846	0.84846	0.84846	0.84846	0.84846	0.84846	0.84846	0.84846	0.84846
13	K46TDPC	0.41281	0.49285	0.73563	0.73335	0.73563	0.73335	0.73563	0.73335	0.73563	0.73563	0.73563	0.73563	0.73563	0.73563
14	K50TDPC	0.37330	0.44423	0.68597	0.68558	0.68597	0.68558	0.68597	0.68558	0.68597	0.68558	0.68597	0.68558	0.68597	0.68558
15	KGTTDPC	0.37330	0.44423	0.68797	0.68558	0.68797	0.68558	0.68797	0.68558	0.68797	0.68558	0.68797	0.68558	0.68797	0.68558

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL DEPTHS FOR TRANSITIONAL CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	JA_TDADJ	FB_TDADJ	MA_TDADJ	AP_TDADJ	MY_TDADJ	JN_TDADJ	JL_TDADJ	AU_TDADJ	SP_TDADJ	OC_TDADJ	NO_TDADJ	DE_TDADJ
1	0.40317	0.34917	0.22956	0.23113	0.22956	0.22956	0.22956	0.22956	0.22956	0.22956	0.22956	0.22956
2	0.42330	0.37286	0.25852	0.26046	0.25852	0.25852	0.25852	0.25852	0.25852	0.25852	0.25852	0.25852
3	0.44432	0.39298	0.27886	0.28103	0.27886	0.27886	0.27886	0.27886	0.27886	0.27886	0.27886	0.27886
4	0.46728	0.41141	0.30122	0.30359	0.30122	0.30122	0.30122	0.30122	0.30122	0.30122	0.30122	0.30122
5	0.48479	0.43195	0.32938	0.33191	0.32938	0.32938	0.32938	0.32938	0.32938	0.32938	0.32938	0.32938
6	0.52249	0.47953	0.35642	0.35886	0.35642	0.35642	0.35642	0.35642	0.35642	0.35642	0.35642	0.35642
7	0.53964	0.50071	0.45937	0.46138	0.45937	0.45937	0.45937	0.45937	0.45937	0.45937	0.45937	0.45937
8	0.51287	0.48841	0.47559	0.47762	0.47559	0.47559	0.47559	0.47559	0.47559	0.47559	0.47559	0.47559
9	0.52009	0.49719	0.49410	0.49610	0.49410	0.49410	0.49410	0.49410	0.49410	0.49410	0.49410	0.49410
10	0.56138	0.52391	0.50761	0.50953	0.50761	0.50761	0.50761	0.50761	0.50761	0.50761	0.50761	0.50761
11	0.54890	0.51928	0.53364	0.53538	0.53364	0.53364	0.53364	0.53364	0.53364	0.53364	0.53364	0.53364
12	0.60061	0.55427	0.55668	0.55839	0.55668	0.55668	0.55668	0.55668	0.55668	0.55668	0.55668	0.55668
13	0.62644	0.56507	0.55511	0.55673	0.55511	0.55511	0.55511	0.55511	0.55511	0.55511	0.55511	0.55511
14	0.63158	0.56701	0.55936	0.56153	0.55936	0.55936	0.55936	0.55936	0.55936	0.55936	0.55936	0.55936
15	0.63158	0.56701	0.55996	0.56153	0.55996	0.55996	0.55996	0.55996	0.55996	0.55996	0.55996	0.55996

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR WIDE CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	NAME_	JA_WDEPC	FB_WDEPC	MA_WDEPC	AP_WDEPC	MY_WDEPC	JN_WDEPC	JL_WDEPC	SP_WDEPC	OC_WDEPC	NO_WDEPC	DE_WDEPC
1	K06WDEPC	0.76320	0.78228	0.52918	0.58396	0.52918	0.52918	0.52918	0.79569	0.79199	0.78612	0.77143
2	K08WDEPC	0.83970	0.77961	0.58810	0.64781	0.58810	0.58810	0.58810	0.76887	0.77314	0.77520	0.77647
3	K10WDEPC	0.90045	0.78248	0.65293	0.71270	0.65293	0.65293	0.65293	0.75010	0.76158	0.77096	0.78880
4	K12WDEPC	0.92145	0.80295	0.68820	0.74612	0.68820	0.68820	0.68820	0.76697	0.77980	0.79061	0.80385
5	K14WDEPC	0.93330	0.80525	0.72447	0.77980	0.72447	0.72447	0.72447	0.76106	0.77675	0.79052	0.81136
6	K16WDEPC	0.94994	0.83625	0.75825	0.81068	0.75825	0.75825	0.75825	0.79453	0.80970	0.82299	0.84503
7	K20WDEPC	0.87631	0.95223	0.84427	0.87571	0.84427	0.84427	0.84427	0.95694	0.95948	0.94919	0.84875
8	K22WDEPC	0.67437	0.87015	0.62291	0.65011	0.62291	0.62291	0.62291	0.91599	0.90311	0.88944	0.85351
9	K22WDEPC	0.62171	0.83129	0.54928	0.57161	0.54928	0.54928	0.54928	0.88363	0.86826	0.85153	0.81177
10	K32WDEPC	0.70625	0.87483	0.60597	0.63573	0.60597	0.60597	0.60597	0.91530	0.90581	0.89075	0.85847
11	K36WDEPC	0.74323	0.85823	0.56860	0.61039	0.56860	0.56860	0.56860	0.88886	0.87972	0.86874	0.84321
12	K40WDEPC	0.86663	0.88850	0.66954	0.72039	0.66954	0.66954	0.66954	0.89046	0.89097	0.88946	0.88240
13	K46WDEPC	0.91221	0.89822	0.73066	0.78175	0.73066	0.73066	0.73066	0.88617	0.89168	0.89520	0.89717
14	K50WDEPC	0.93400	0.84414	0.75301	0.80674	0.75301	0.75301	0.75301	0.80887	0.82207	0.83333	0.85081
15	KGTWDEPC	0.93400	0.84414	0.75301	0.80674	0.75301	0.75301	0.75301	0.80887	0.82207	0.83333	0.85081

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL DEPTHS FOR WIDE CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	JA_WDADJ	FB_WDADJ	MA_WDADJ	AP_WDADJ	MY_WDADJ	JN_WDADJ	JL_WDADJ	AU_WDADJ	SP_WDADJ	OC_WDADJ	NO_WDADJ	DE_WDADJ
1	0.07501	0.70048	0.38759	0.40353	0.38759	0.38759	0.38759	0.64122	0.66002	0.67921	0.72039	0.83182
2	0.89679	0.71206	0.40979	0.42738	0.40979	0.40979	0.40979	0.64305	0.66486	0.68724	0.73548	0.85957
3	0.87834	0.75223	0.44985	0.46851	0.44985	0.44985	0.44985	0.67103	0.69667	0.72311	0.78023	0.84547
4	0.87751	0.77000	0.46497	0.48339	0.46497	0.46497	0.46497	0.68564	0.71233	0.73991	0.79934	0.84375
5	0.84510	0.80758	0.49751	0.51610	0.49751	0.49751	0.49751	0.71578	0.74485	0.77499	0.83983	0.81282
6	0.82476	0.84675	0.52288	0.54123	0.52288	0.52288	0.52288	0.52288	0.75185	0.78204	0.81336	0.88034
7	0.90229	0.79181	0.48240	0.49314	0.48240	0.48240	0.48240	0.50008	0.51008	0.72115	0.74461	0.76896
8	0.67216	0.90863	0.51008	0.51968	0.51008	0.51008	0.51008	0.51008	0.84579	0.86665	0.88821	0.92163
9	0.56581	0.81885	0.55855	0.56950	0.55855	0.55855	0.55855	0.55855	0.92713	0.89154	0.85578	0.78304
10	0.55543	0.78226	0.62056	0.63529	0.62056	0.62056	0.62056	0.62056	0.87957	0.84765	0.81537	0.74942
11	0.48551	0.66636	0.70843	0.73103	0.70843	0.70843	0.70843	0.74215	0.71605	0.69949	0.63592	0.45476
12	0.50600	0.65631	0.77454	0.80222	0.77454	0.77454	0.77454	0.72311	0.70125	0.67867	0.63224	0.7905
13	0.49677	0.63208	0.83796	0.86712	0.83796	0.83796	0.83796	0.69127	0.67216	0.65224	0.61054	0.47182
14	0.49285	0.60236	0.86528	0.89637	0.86528	0.86528	0.86528	0.65030	0.63508	0.61892	0.58426	0.47174
15	0.49285	0.60236	0.86528	0.89637	0.86528	0.86528	0.86528	0.65030	0.63508	0.61892	0.58426	0.47174

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR DIVIDED CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	_NAME_	JA_DVEPC	FB_DVEPC	MA_DVEPC	AP_DVEPC	MY_DVEPC	JN_DVEPC	JL_DVEPC	AU_DVEPC	SP_DVEPC	OC_DVEPC	NO_DVEPC	DE_DVEPC
1	K06DVEPC	0.41144	0.23318	0.22555	0.23609	0.22555	0.22555	0.22555	0.09749	0.15262	0.19717	0.26230	0.44086
2	K08DVEPC	0.72819	0.57286	0.19125	0.1815	0.19125	0.19125	0.19125	0.42165	0.48519	0.53449	0.60278	0.75660
3	K10DVEPC	0.85795	0.75548	0.37813	0.36937	0.37813	0.37813	0.37813	0.63991	0.69119	0.72843	0.77502	0.87575
4	K12DVEPC	0.85001	0.72656	0.25799	0.25902	0.26799	0.26799	0.26799	0.59604	0.65279	0.69503	0.75008	0.86654
5	K14DVEPC	0.92400	0.86107	0.35154	0.33605	0.35154	0.35154	0.35154	0.76991	0.81222	0.84121	0.87436	0.93890
6	K16DVEPC	0.91229	0.89381	0.52782	0.51183	0.52782	0.52782	0.52782	0.84021	0.86729	0.89881	0.92988	
7	K20DVEPC	0.68291	0.80116	0.73428	0.71631	0.73428	0.73428	0.73428	0.85747	0.84101	0.82148	0.78116	0.69605
8	K24DVEPC	0.55845	0.70408	0.75394	0.73686	0.75394	0.75394	0.75394	0.79203	0.76174	0.73200	0.67839	0.57424
9	K28DVEPC	0.44410	0.58628	0.80263	0.78855	0.80263	0.80263	0.80263	0.68930	0.65079	0.61652	0.55958	0.46597
10	K32DVEPC	0.37089	0.48973	0.88219	0.85458	0.88219	0.86219	0.86219	0.57911	0.54527	0.51563	0.46700	0.3914
11	K36DVEPC	0.37216	0.48866	0.8944	0.84182	0.84944	0.84944	0.84944	0.57205	0.53953	0.51199	0.46881	0.38304
12	K40DVEPC	0.37163	0.48320	0.84951	0.84255	0.84951	0.84951	0.84951	0.56065	0.53014	0.50459	0.46522	0.37688
13	K46DVEPC	0.27197	0.37418	0.82197	0.81893	0.82197	0.82197	0.82197	0.41710	0.41710	0.39343	0.35846	0.27051
14	K50DVEPC	0.25736	0.36417	0.77181	0.76792	0.77181	0.77181	0.77181	0.44019	0.44019	0.38429	0.34787	0.25427
15	KGTDVEPC	0.25736	0.36417	0.77181	0.76792	0.77181	0.77181	0.77181	0.44019	0.44019	0.38429	0.34787	0.25427

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR DIVIDED CHANNEL CATEGORY - HIGH FLOW YEAR

CBS	JA_DVADJ	FB_DVADJ	MA_DVADJ	AP_DVADJ	MY_DVADJ	JN_DVADJ	JL_DVADJ	AU_DVADJ	SP_DVADJ	OC_DVADJ	NO_DVADJ	DE_DVADJ
1	0.43153	0.34911	0.20355	0.20696	0.20355	0.20355	0.20355	0.30089	0.31936	0.33527	0.36128	0.44161
2	0.53142	0.44527	0.19785	0.19894	0.19785	0.19785	0.19785	0.41151	0.42274	0.45873	0.53500	
3	0.63876	0.55884	0.25738	0.25782	0.25738	0.25738	0.25738	0.55557	0.52692	0.5432	0.57128	0.64648
4	0.76726	0.66304	0.28567	0.28596	0.28567	0.28567	0.28567	0.59356	0.62121	0.64394	0.67946	0.77603
5	0.79794	0.71470	0.30450	0.30345	0.30450	0.30450	0.30450	0.65822	0.68109	0.69947	0.72771	0.80611
6	0.83562	0.76628	0.36267	0.36179	0.36267	0.36267	0.36267	0.72107	0.73947	0.75113	0.77675	0.84540
7	0.82795	0.84751	0.47874	0.47763	0.47874	0.47874	0.47874	0.84640	0.84783	0.84785	0.84731	0.8235
8	0.71719	0.84690	0.51673	0.51673	0.51673	0.51673	0.51673	0.87298	0.86735	0.86188	0.82507	0.72266
9	0.63675	0.75537	0.55521	0.55521	0.55521	0.55521	0.55521	0.83066	0.80318	0.77114	0.73458	0.64655
10	0.54852	0.64373	0.63206	0.63459	0.63206	0.63206	0.63206	0.70460	0.66204	0.62701	0.5684	
11	0.52613	0.61644	0.65505	0.65765	0.65505	0.65505	0.65505	0.67220	0.65137	0.63291	0.60161	0.52900
12	0.50341	0.58788	0.68338	0.68734	0.68338	0.68438	0.68438	0.63875	0.61967	0.60285	0.57445	0.50409
13	0.46684	0.54467	0.67419	0.67853	0.67419	0.67419	0.67419	0.59194	0.57390	0.55331	0.53259	0.46515
14	0.46147	0.54071	0.65563	0.65950	0.65563	0.65563	0.65563	0.58945	0.57070	0.55465	0.52844	0.45920
15	0.46147	0.54071	0.65563	0.65950	0.65563	0.65563	0.65563	0.58945	0.57070	0.55465	0.52844	0.45920

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR NARROW CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	_NAME_	JA_NVEPC	FB_NVEPC	MA_NVEPC	AP_NVEPC	MY_NVEPC	JN_NVEPC	JL_NVEPC	AU_NVEPC	SP_NVEPC	OC_NVEPC	NO_NVEPC	DE_NVEPC
1	K06NVEPC	-0.18393	-0.26223	-0.24284	-0.24440	-0.24284	-0.24284	-0.24284	-0.24284	-0.27580	-0.27005	-0.26537	-0.17173
2	K08NVEPC	-0.10723	-0.20468	-0.27692	-0.27819	-0.27692	-0.27692	-0.27692	-0.27692	-0.22932	-0.22009	-0.21169	-0.02669
3	K10NVEPC	0.17102	-0.00571	-0.20350	-0.30550	-0.30350	-0.30350	-0.30350	-0.30350	-0.06810	-0.04695	-0.02617	0.29738
4	K12NVEPC	0.39952	0.17316	-0.29108	-0.29314	-0.29108	-0.29108	-0.29108	-0.29108	0.08333	0.11321	0.14282	0.20358
5	K14NVEPC	0.55494	0.33063	-0.31495	-0.31398	-0.31495	-0.31495	-0.31495	-0.31495	0.25933	0.29490	0.35586	0.66397
6	K16NVEPC	0.76637	0.54292	-0.29412	-0.28852	-0.29412	-0.29412	-0.29412	-0.29412	0.42613	0.46589	0.50445	0.57775
7	K20NVEPC	0.80292	0.96211	0.13822	0.17321	0.13822	0.13822	0.13822	0.13822	0.94730	0.95474	0.95895	0.96227
8	K24NVEPC	0.64840	0.90982	0.41817	0.45443	0.41817	0.41817	0.41817	0.41817	0.93269	0.92039	0.89699	0.57109
9	K28NVEPC	0.47685	0.82228	0.61052	0.64594	0.61052	0.61052	0.61052	0.61052	0.89280	0.86746	0.84361	0.79965
10	K32NVEPC	0.22252	0.80407	0.61828	0.65487	0.61828	0.61828	0.61828	0.61828	0.88132	0.85430	0.82824	0.77777
11	K36NVEPC	0.27356	0.70904	0.67931	0.71544	0.67931	0.67931	0.67931	0.67931	0.80486	0.77141	0.73923	0.67732
12	K40NVEPC	0.19581	0.60556	0.72903	0.76151	0.72903	0.72903	0.72903	0.72903	0.71166	0.67314	0.63766	0.57517
13	K46NVEPC	0.14007	0.33826	0.94188	0.95034	0.94188	0.94188	0.94188	0.94188	0.44754	0.40080	0.36485	0.31270
14	K50NVEPC	0.09383	0.26032	0.96549	0.96761	0.96549	0.96549	0.96549	0.96549	0.37027	0.32223	0.28565	0.23638
15	KOTNVEPC	0.09383	0.26032	0.95549	0.96761	0.95549	0.96549	0.96549	0.96549	0.37027	0.32223	0.28565	0.23628

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR NARROW CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	JA_NVADJ	FB_NVADJ	MA_NVADJ	AP_NVADJ	MY_NVADJ	JN_NVADJ	JL_NVADJ	AU_NVADJ	SP_NVADJ	OC_NVADJ	NO_NVADJ	DE_NVADJ
1	0.34606	0.31565	0.36964	0.36887	0.36964	0.36964	0.36964	0.36964	0.31351	0.31477	0.31555	0.31577
2	0.37858	0.34027	0.35100	0.35238	0.35300	0.35300	0.35300	0.35300	0.33355	0.33332	0.33861	0.34207
3	0.49657	0.12541	0.34002	0.33905	0.34002	0.34002	0.34002	0.34002	0.40343	0.41098	0.41829	0.43263
4	0.58410	0.49401	0.34062	0.33963	0.34062	0.34062	0.34062	0.34062	0.46184	0.47247	0.48314	0.50482
5	0.64897	0.56032	0.32815	0.32962	0.32915	0.32915	0.32915	0.32915	0.52119	0.53448	0.54743	0.57289
6	0.73721	0.4972	0.3316	0.34185	0.33916	0.33916	0.33916	0.33916	0.60764	0.62225	0.63602	0.66260
7	0.73776	0.81009	0.55269	0.53620	0.55269	0.53620	0.53620	0.53620	0.81349	0.81198	0.80596	0.71550
8	0.62657	0.73243	0.62058	0.63645	0.62058	0.62058	0.62058	0.62058	0.75464	0.74705	0.73939	0.72465
9	0.53582	0.66707	0.67270	0.68749	0.67270	0.67270	0.67270	0.67270	0.70109	0.68900	0.67754	0.65519
10	0.50057	0.64052	0.65538	0.67041	0.65558	0.65558	0.65558	0.65558	0.77585	0.663355	0.65166	0.64923
11	0.44411	0.60131	0.67417	0.68868	0.67417	0.67417	0.67417	0.67417	0.64253	0.62817	0.61434	0.58817
12	0.40167	0.54447	0.66881	0.68117	0.66881	0.66881	0.66881	0.66881	0.58695	0.57151	0.55720	0.53173
13	0.32550	0.38551	0.63128	0.64106	0.63128	0.63128	0.63128	0.63128	0.42192	0.40671	0.39472	0.37665
14	0.31230	0.36306	0.64604	0.64674	0.64604	0.64604	0.64604	0.64604	0.38390	0.37182	0.35473	0.29802
15	0.31230	0.36306	0.64604	0.64674	0.64604	0.64604	0.64604	0.64604	0.38390	0.37182	0.35473	0.29802

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR TRANSITIONAL CHANNEL CATEGORY - HIGH FLOW

OBS	_NAME_	JA_TVPC	FB_TVPC	MA_TVPC	MY_TVPC	AP_TVPC	JN_TVPC	JL_TVPC	AU_TVPC	SP_TVPC	OC_TVPC	NO_TVPC	DE_TVPC
1	K06TVPC	0.70100	0.68316	0.17377	0.18785	0.17377	0.17377	0.17377	0.59718	0.62982	0.65823	0.70517	0.69656
2	K08TVPC	0.81935	0.77557	0.34413	0.35781	0.34413	0.34413	0.34413	0.73519	0.70986	0.75686	0.79180	0.81813
3	K10TVPC	0.89208	0.76910	0.42282	0.43464	0.42282	0.42282	0.42282	0.71948	0.73877	0.75512	0.78111	0.89108
4	K12TVPC	0.92622	0.58233	0.34552	0.35476	0.34552	0.34652	0.34652	0.54966	0.56240	0.57316	0.59019	0.91923
5	K14TVPC	0.92998	0.59004	0.38331	0.39073	0.38331	0.38331	0.38331	0.56257	0.57336	0.59652	0.92218	
6	K16TVPC	0.85661	0.38837	0.19943	0.20584	0.19943	0.19943	0.19943	0.36090	0.37150	0.38055	0.39515	0.85399
7	K20TVPC	0.72124	0.92852	0.49552	0.51111	0.49552	0.49552	0.49552	0.87222	0.89466	0.91317	0.94130	0.73012
8	K24TVPC	0.73595	0.96826	0.63910	0.65260	0.63910	0.63910	0.63910	0.93227	0.94711	0.95889	0.97568	0.74928
9	K28TVPC	0.72927	0.98033	0.76108	0.77203	0.76108	0.76108	0.76108	0.96853	0.97447	0.97824	0.98111	0.74661
10	K32TVPC	0.58639	0.95177	0.84352	0.85088	0.84352	0.84352	0.84352	0.95920	0.95786	0.95527	0.94757	0.70695
11	K36TVPC	0.64063	0.90960	0.88852	0.90313	0.88852	0.88852	0.88852	0.93578	0.92745	0.91866	0.90040	0.66347
12	K40TVPC	0.63974	0.90854	0.90219	0.90679	0.90219	0.90219	0.90219	0.93511	0.92661	0.91769	0.89928	0.66268
13	K46TVPC	0.55671	0.83217	0.92478	0.92539	0.92478	0.92478	0.92478	0.87167	0.85807	0.84490	0.81987	0.58155
14	K50TVPC	0.50897	0.78520	0.92461	0.92338	0.92461	0.92461	0.92461	0.83196	0.81558	0.80001	0.77106	0.53450
15	KGTTVPC	0.50897	0.78520	0.92461	0.92338	0.92461	0.92461	0.92461	0.83196	0.81558	0.80001	0.77106	0.53450

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL VELOCITIES FOR TRANSITIONAL CHANNEL CATEGORY - HIGH

OBS	JA_TVADJ	FB_TVADJ	MA_TVADJ	MY_TVADJ	AP_TVADJ	JN_TVADJ	JL_TVADJ	AU_TVADJ	SP_TVADJ	OC_TVADJ	NO_TVADJ	DE_TVADJ	
1	0.35431	0.29929	0.17636	0.17923	0.17636	0.17636	0.17636	0.27686	0.28490	0.29235	0.30584	0.37341	
2	0.40973	0.34073	0.21795	0.22110	0.21795	0.21795	0.21795	0.31987	0.32735	0.33427	0.34683	0.43186	
3	0.45741	0.36510	0.24813	0.25123	0.24813	0.24813	0.24813	0.24813	0.34593	0.35277	0.35913	0.37077	0.48307
4	0.50671	0.35534	0.25550	0.25816	0.25550	0.25550	0.25550	0.25550	0.33925	0.34493	0.35027	0.36021	0.53348
5	0.52289	0.37076	0.27255	0.27517	0.27255	0.27255	0.27255	0.27255	0.35518	0.36066	0.36583	0.37550	0.55507
6	0.58898	0.37398	0.27299	0.27562	0.27299	0.27299	0.27299	0.27299	0.35735	0.36318	0.36870	0.37907	0.61815
7	0.56204	0.53759	0.35225	0.35743	0.35225	0.35225	0.35225	0.50876	0.51921	0.52876	0.54585	0.59696	
8	0.57958	0.56098	0.39474	0.39967	0.39474	0.39474	0.39474	0.39674	0.53686	0.54556	0.55355	0.56799	0.61712
9	0.59954	0.58612	0.44042	0.44503	0.44042	0.44042	0.44042	0.44042	0.56796	0.57450	0.58050	0.59144	0.63986
10	0.60979	0.60248	0.48084	0.48480	0.48084	0.48084	0.48084	0.48084	0.58955	0.59414	0.59841	0.60641	0.65219
11	0.62858	0.62458	0.52468	0.52818	0.52468	0.52468	0.52468	0.52468	0.35735	0.36318	0.36870	0.37907	
12	0.68460	0.68024	0.57286	0.57665	0.57286	0.57286	0.57286	0.57286	0.61975	0.62219	0.62697	0.67344	
13	0.69025	0.69352	0.61561	0.61841	0.61561	0.61561	0.61561	0.61561	0.67234	0.67766	0.68281	0.73351	
14	0.69397	0.70088	0.63846	0.64076	0.63846	0.63846	0.63846	0.63846	0.69142	0.69237	0.69484	0.74059	
15	0.69397	0.70088	0.63846	0.64076	0.63846	0.63846	0.63846	0.63846	0.70113	0.70074	0.70136	0.74570	

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR WIDE CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	NAME	JA_WVEPC	FB_WVEPC	MA_WVEPC	AP_WVEPC	MY_WVEPC	JN_WVEPC	JL_WVEPC	AU_WVEPC	SP_WVEPC	OC_WVEPC	NO_WVEPC	DE_WVEPC
1	K06WVEPC	0.26729	0.35606	0.12328	0.12664	0.12328	0.12328	0.12328	0.12328	0.34256	0.34733	0.35184	0.36001
2	K08WVEPC	0.46203	0.53047	0.24969	0.25512	0.24969	0.24969	0.24969	0.24969	0.52835	0.52947	0.53019	0.53033
3	K10WVEPC	0.61985	0.67032	0.40744	0.41298	0.40744	0.40744	0.40744	0.40744	0.66572	0.66843	0.66964	0.67049
4	K12WVEPC	0.75434	0.78665	0.53006	0.53562	0.53006	0.53006	0.53006	0.53006	0.78833	0.78870	0.78798	0.78471
5	K14WVEPC	0.78376	0.81862	0.58805	0.59276	0.58805	0.58805	0.58805	0.58805	0.81505	0.81685	0.81805	0.81858
6	K16WVEPC	0.84581	0.87812	0.67736	0.68145	0.67736	0.67736	0.67736	0.67736	0.87182	0.87456	0.87567	0.87892
7	K20WVEPC	0.66481	0.89574	0.70742	0.71127	0.70742	0.70742	0.70742	0.70742	0.88835	0.89146	0.89394	0.89688
8	K24WVEPC	0.81386	0.85613	0.73461	0.73697	0.73461	0.73461	0.73461	0.73461	0.83244	0.84092	0.84883	0.86381
9	K28WVEPC	0.85844	0.89575	0.72281	0.72632	0.72281	0.72281	0.72281	0.72281	0.88895	0.89268	0.89816	0.89411
10	K32WVEPC	0.92423	0.95191	0.78204	0.78615	0.78204	0.78204	0.78204	0.78204	0.94827	0.95017	0.95140	0.95172
11	K36WVEPC	0.99280	0.98299	0.88833	0.90173	0.88833	0.89833	0.89833	0.89833	0.97286	0.97692	0.98031	0.98396
12	K40WVEPC	0.96136	0.97514	0.93758	0.94174	0.93758	0.93758	0.93758	0.93758	0.96487	0.96696	0.97240	0.97720
13	K46WVEPC	0.83732	0.89990	0.97479	0.95139	0.97479	0.94749	0.94749	0.94749	0.88315	0.88832	0.89491	0.90426
14	K50WVEPC	0.85541	0.86581	0.94048	0.94164	0.94048	0.94048	0.94048	0.94048	0.84946	0.85547	0.86092	0.87009
15	K54WVEPC	0.85541	0.86581	0.94048	0.94164	0.94048	0.94048	0.94048	0.94048	0.84946	0.85547	0.86092	0.87009

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL VELOCITIES FOR WIDE CHANNEL CATEGORY - HIGH FLOW YEAR

OBS	JA_WVADJ	FB_WVADJ	MA_WVADJ	AP_WVADJ	MY_WVADJ	JN_WVADJ	JL_WVADJ	AU_WVADJ	SP_WVADJ	OC_WVADJ	NO_WVADJ	DE_WVADJ	
1	0.62891	0.53297	0.28471	0.28703	0.28471	0.28471	0.28471	0.28471	0.47942	0.49624	0.51407	0.55307	
2	0.71268	0.61237	0.32247	0.32553	0.32247	0.32247	0.32247	0.32247	0.55561	0.57350	0.59239	0.63357	
3	0.74856	0.70490	0.38304	0.38652	0.38304	0.38304	0.38304	0.38304	0.63906	0.65983	0.68174	0.72944	
4	0.80119	0.76304	0.42142	0.42511	0.42142	0.42142	0.42142	0.42142	0.69412	0.71589	0.73883	0.78867	
5	0.77772	0.81356	0.45815	0.46186	0.45815	0.45815	0.45815	0.45815	0.73772	0.76167	0.78691	0.84178	
6	0.78072	0.86606	0.49882	0.50260	0.49882	0.49882	0.49882	0.49882	0.78423	0.81007	0.83731	0.89651	
7	0.89676	0.76890	0.44661	0.44991	0.44661	0.44661	0.44661	0.44661	0.69587	0.71893	0.74324	0.79607	
8	0.72815	0.90182	0.54351	0.54704	0.54351	0.54351	0.54351	0.54351	0.80891	0.83820	0.86912	0.92636	
9	0.64840	0.84778	0.62211	0.62557	0.62211	0.62211	0.62211	0.62211	0.92760	0.90141	0.87480	0.82038	
10	0.62639	0.14442	0.68859	0.69371	0.68859	0.68859	0.68859	0.68859	0.89471	0.86859	0.84152	0.78703	
11	0.54666	0.70789	0.85735	0.86329	0.85735	0.85735	0.85735	0.85735	0.77515	0.75308	0.73065	0.68483	
12	0.53179	0.68642	0.89889	0.90543	0.89889	0.89889	0.89889	0.89889	0.75157	0.73018	0.70846	0.66408	
13	0.49030	0.32264	0.94294	0.94967	0.94294	0.94294	0.94294	0.94294	0.69017	0.67132	0.65214	0.61282	
14	0.47282	0.60944	0.95781	0.96329	0.95781	0.95781	0.95781	0.95781	0.95781	0.66489	0.64672	0.62823	0.59035
15	0.47282	0.60944	0.95781	0.96329	0.95781	0.95781	0.95781	0.95781	0.95781	0.66489	0.64672	0.62823	0.44468

COMBINED ADJUSTED COEFFICIENTS FOR DEPTH UNDER LOW FLOWS

OBS	JA_IMPTD	FB_IMPTD	MA_IMPTD	AP_IMPTD	MY_IMPTD	JN_IMPTD	JL_IMPTD	AU_IMPTD	SP_IMPTD	OC_IMPTD	NO_IMPTD	DE_IMPTD
1	0.69885	0.68992	0.40986	0.54350	0.55769	0.30428	0.42326	0.68873	0.68892	0.68873	0.68992	0.68655
2	0.69101	0.71310	0.42446	0.52249	0.54352	0.32447	0.44314	0.71439	0.71310	0.71439	0.71310	0.67235
3	0.69753	0.72701	0.45366	0.54138	0.55944	0.35173	0.47031	0.72854	0.72701	0.72854	0.72701	0.67879
4	0.70701	0.74631	0.48467	0.54129	0.55369	0.3293	0.50810	0.74991	0.74631	0.74991	0.74631	0.67016
5	0.68140	0.73242	0.51580	0.53611	0.54214	0.41610	0.54464	0.73736	0.73242	0.73736	0.73242	0.64413
6	0.67842	0.74296	0.34683	0.55709	0.55319	0.44038	0.58373	0.74948	0.74296	0.74948	0.74296	0.64309
7	0.70622	0.76326	0.55244	0.62480	0.60387	0.42805	0.58448	0.76643	0.76326	0.76643	0.76326	0.68227
8	0.61038	0.65597	0.56909	0.66170	0.61470	0.44069	0.62248	0.65986	0.65597	0.65986	0.65597	0.59251
9	0.56742	0.60997	0.60489	0.68486	0.63575	0.47289	0.66271	0.61374	0.60997	0.61374	0.60997	0.55149
10	0.55296	0.59758	0.65762	0.65229	0.66181	0.52292	0.69945	0.60222	0.59758	0.60222	0.59758	0.53673
11	0.51199	0.56357	0.68981	0.61984	0.68695	0.58200	0.68462	0.56889	0.56357	0.56889	0.56357	0.48177
12	0.47186	0.55205	0.71079	0.59458	0.67113	0.63571	0.68314	0.55896	0.55205	0.55896	0.55205	0.44057
13	0.44671	0.52182	0.64742	0.57869	0.646661	0.58950	0.62223	0.52730	0.52182	0.52730	0.52182	0.42175
14	0.43067	0.52193	0.65035	0.56019	0.63166	0.61476	0.6108	0.52805	0.52193	0.52805	0.52193	0.40478
15	0.43067	0.52193	0.65035	0.56019	0.63166	0.61476	0.61808	0.52805	0.52193	0.52805	0.52193	0.40478

COMBINED ADJUSTED COEFFICIENTS FOR VELOCITY FOR LOW FLOWS

OBS	JA_IMPTV	FB_IMPTV	MA_IMPTV	AP_IMPTV	MY_IMPTV	JN_IMPTV	JL_IMPTV	AU_IMPTV	SP_IMPTV	OC_IMPTV	NO_IMPTV	DE_IMPTV
1	0.52732	0.44892	0.31834	0.34195	0.31042	0.27584	0.33423	0.44643	0.44892	0.44643	0.44892	0.54019
2	0.61941	0.52225	0.35191	0.38804	0.34075	0.29149	0.37551	0.52033	0.52255	0.52033	0.52255	0.63755
3	0.69995	0.60279	0.39993	0.44725	0.38457	0.32243	0.42740	0.6015	0.60279	0.6015	0.60279	0.71458
4	0.74309	0.67541	0.43157	0.49123	0.41406	0.34087	0.46623	0.67376	0.67541	0.67376	0.67541	0.72619
5	0.74281	0.69435	0.46241	0.53436	0.44251	0.35582	0.50492	0.6934	0.69435	0.6934	0.69435	0.71751
6	0.72501	0.72812	0.50834	0.58540	0.48584	0.38058	0.55428	0.73965	0.73812	0.73965	0.73812	0.63353
7	0.69077	0.74307	0.62765	0.68698	0.60720	0.45812	0.66621	0.75020	0.74307	0.75020	0.74307	0.66728
8	0.60814	0.64087	0.67129	0.71498	0.65307	0.53105	0.69908	0.64795	0.64087	0.64795	0.64087	0.59139
9	0.55840	0.58569	0.72319	0.74828	0.7056	0.58812	0.74069	0.59015	0.58569	0.59015	0.58569	0.54588
10	0.53049	0.56002	0.76473	0.75683	0.74623	0.62474	0.76624	0.56307	0.56002	0.56307	0.56002	0.53970
11	0.49536	0.51824	0.78904	0.70641	0.79727	0.69906	0.74046	0.52083	0.51824	0.52083	0.51824	0.46721
12	0.46590	0.51203	0.78455	0.68830	0.79365	0.72574	0.72257	0.51311	0.51203	0.51311	0.51203	0.43921
13	0.42119	0.47705	0.70722	0.61099	0.72008	0.73886	0.6333	0.47643	0.47705	0.47643	0.47705	0.36228
14	0.40245	0.46847	0.68910	0.59850	0.70200	0.74860	0.62945	0.46847	0.46847	0.46847	0.46847	0.37853
15	0.40245	0.46847	0.68910	0.59850	0.70200	0.74860	0.62945	0.46847	0.46847	0.46847	0.46847	0.37853

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR DIVIDED CHANNEL CATEGORY - LOW FLOW YEAR

OBS	NAME	JA_DDEPC	FB_DDEPC	MA_DDEPC	AP_DDEPC	MY_DDEPC	JN_DDEPC	JL_DDEPC	AU_DDEPC	SP_DDEPC	OC_DDEPC	NO_DDEPC	DE_DDEPC
1	K03DDEPC	0.922792	0.83837	0.565556	0.40092	0.54971	0.53613	0.44314	0.80254	0.83837	0.91044		
2	K03DDEPC	0.822807	0.12051	0.45224	0.56586	0.45433	0.36290	0.57122	0.91109	0.92051	0.77962		
3	K10DDEPC	0.89223	0.55470	0.5081	0.60701	0.54939	0.46792	0.62024	0.94207	0.95470	0.85185		
4	K12DDEPC	0.93888	0.57366	0.64257	0.64651	0.63839	0.56611	0.66630	0.95877	0.97366	0.90594		
5	K14DDEPC	0.94951	0.98013	0.68127	0.67270	0.67675	0.60521	0.69488	0.96557	0.98013	0.92033		
6	K16DDEPC	0.91980	0.8878	0.65406	0.70591	0.65365	0.56556	0.72011	0.8007	0.98878	0.8834		
7	K20DDEPC	0.96838	0.56038	0.83562	0.74801	0.82958	0.77209	0.78217	0.94510	0.96038	0.95477		
8	K24DDEPC	0.88755	0.97596	0.80578	0.86810	0.81194	0.70963	0.88422	0.97678	0.97556	0.86015		
9	K28DDEPC	0.89455	0.96733	0.83356	0.86841	0.83872	0.74307	0.88859	0.96649	0.96733	0.87087		
10	K32DDEPC	0.92228	0.6331	0.85266	0.83706	0.85403	0.77256	0.86366	0.95744	0.96331	0.90361		
11	K36DDEPC	0.83815	0.55767	0.80307	0.91253	0.81446	0.69774	0.92371	0.96477	0.95767	0.80773		
12	K40DDEPC	0.76313	0.92465	0.77589	0.95090	0.79396	0.66030	0.95463	0.93972	0.92465	0.72772		
13	K46DDEPC	0.67621	0.37499	0.73968	0.97314	0.76424	0.1729	0.97032	0.59747	0.87459	0.87499	0.63659	
14	K50DDEPC	0.62148	0.83200	0.73529	0.98467	0.76296	0.61203	0.98040	0.85817	0.83200	0.83200	0.58280	
15	KGTDDDEPC	0.62148	0.83200	0.73529	0.98467	0.76296	0.61203	0.98040	0.85817	0.83200	0.83200	0.58260	

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL DEPTHS FOR DIVIDED CHANNEL CATEGORY - LOW FLOW YEAR

OBS	JA_DDADJ	FB_DDADJ	MA_DDADJ	AP_DDADJ	MY_DDADJ	JN_DDADJ	JL_DDADJ	AU_DDADJ	SP_DDADJ	OC_DDADJ	NO_DDADJ	DE_DDADJ
1	0.71595	0.56533	0.34252	0.38535	0.33258	0.25513	0.36865	0.55246	0.56533	0.55246	0.56533	0.76135
2	0.67887	0.59059	0.31773	0.43073	0.31211	0.22636	0.40136	0.58573	0.59059	0.58573	0.59059	0.70921
3	0.79018	0.67594	0.38153	0.49707	0.37391	0.27415	0.46541	0.66933	0.67594	0.66933	0.67594	0.82987
4	0.96182	0.82332	0.48749	0.61437	0.47695	0.35284	0.57761	0.81437	0.82332	0.81437	0.82332	0.88141
5	0.96749	0.82602	0.49897	0.62215	0.48813	0.36165	0.58730	0.81720	0.82602	0.81720	0.82602	0.88007
6	0.90425	0.87412	0.51722	0.67068	0.50723	0.37163	0.62801	0.86739	0.87412	0.86739	0.87412	0.82707
7	0.79726	0.95885	0.66750	0.79918	0.65261	0.48918	0.75667	0.95457	0.95885	0.95885	0.95885	0.73779
8	0.71513	0.90404	0.70200	0.91307	0.69095	0.50453	0.85524	0.90745	0.90404	0.90404	0.90404	0.65672
9	0.68774	0.86242	0.74393	0.91568	0.73179	0.53687	0.89472	0.86495	0.86242	0.86242	0.86242	0.63237
10	0.63322	0.78099	0.82836	0.81698	0.81315	0.60164	0.89248	0.78127	0.78099	0.78099	0.78099	0.58434
11	0.58026	0.74628	0.84126	0.81507	0.83042	0.60132	0.88283	0.75150	0.74628	0.74628	0.74628	0.53177
12	0.53275	0.70228	0.86565	0.79583	0.85777	0.61436	0.85561	0.71015	0.70228	0.71015	0.70228	0.48667
13	0.50648	0.68416	0.84799	0.80490	0.84355	0.59845	0.86550	0.69468	0.68416	0.69468	0.68416	0.46011
14	0.48994	0.66847	0.84585	0.80960	0.84294	0.59650	0.86993	0.68029	0.66847	0.66847	0.66847	0.44561
15	0.48994	0.66847	0.84585	0.80960	0.84294	0.59650	0.86993	0.68029	0.66847	0.66847	0.66847	0.44561

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR NARROW CHANNEL CATEGORY - LOW FLOW YEAR

OBS	NAME	JA_NDEPC	FB_NDEPC	MA_NDEPC	AP_NDEPC	MY_NDEPC	JN_NDEPC	JL_NDEPC	AU_NDEPC	SP_NDEPC	OC_NDEPC	NO_NDEPC	DE_NDEPC
1	K06NDEPC	0.89976	0.87640	-0.19488	0.67239	0.92758	-0.40431	-0.15600	0.85605	0.87640	0.85622	0.87640	0.85622
2	K08NDEPC	0.83000	0.92331	-0.16756	0.45306	0.77601	-0.33476	-0.10362	0.91535	0.92331	0.91535	0.92331	0.76387
3	K10NDEPC	0.81084	0.93960	-0.14979	0.40010	0.72318	-0.31581	-0.06812	0.93611	0.92960	0.93611	0.92960	0.73940
4	K12NDEPC	0.71208	0.93511	-0.07936	0.23533	0.54625	-0.23584	0.05106	0.94448	0.93511	0.94448	0.93511	0.2857
5	K14NDEPC	0.57035	0.87011	0.01520	0.07550	0.34764	-0.13509	0.19586	0.89171	0.87011	0.89171	0.87011	0.48085
6	K16NDEPC	0.52238	0.84417	0.11187	0.04563	0.29204	-0.07760	0.31624	0.87028	0.84417	0.87028	0.84417	0.43245
7	K20NDEPC	0.80336	0.81176	0.08959	0.40300	0.53950	-0.31994	0.18680	0.80704	0.81176	0.80704	0.81176	0.79527
8	K24NDEPC	0.76650	0.77967	0.11193	0.36685	0.49820	-0.28418	0.20385	0.77629	0.77967	0.77629	0.77967	0.75999
9	K28NDEPC	0.72380	0.77544	0.18092	0.31713	0.45597	-0.19135	0.27169	0.78115	0.77944	0.78115	0.77944	0.70845
10	K32NDEPC	0.63993	0.76662	0.29462	0.23481	0.38328	-0.02671	0.38026	0.77703	0.76682	0.77703	0.76682	0.60899
11	K36NDEPC	0.50890	0.71568	0.42077	0.12929	0.28128	0.17826	0.49412	0.73562	0.71568	0.73562	0.71568	0.46021
12	K40NDEPC	0.29150	0.55244	0.52770	-0.01919	0.11228	0.43172	0.56466	0.58056	0.55244	0.58056	0.55244	0.23446
13	K46NDEPC	0.42911	0.48801	0.24967	0.08814	0.18133	0.05070	0.28883	0.49490	0.48801	0.49490	0.48801	0.42775
14	K50NDEPC	0.37685	0.50221	0.34822	0.03998	0.14624	0.20237	0.38271	0.51640	0.50221	0.51640	0.50221	0.35862
15	KGTNDEPC	0.37685	0.50221	0.34822	0.03998	0.14624	0.20237	0.38271	0.51640	0.50221	0.51640	0.50221	0.35862

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND OPERATIONAL DEPTHS FOR NARROW CHANNEL CATEGORY - LOW FLOW YEAR

OBS	JA_NDADJ	FB_NDADJ	MA_NDADJ	AP_NDADJ	MY_NDADJ	JN_NDADJ	JL_NDADJ	AU_NDADJ	SP_NDADJ	OC_NDADJ	NO_NDADJ	DE_NDADJ
1	0.78636	0.79490	0.36995	0.72611	0.89181	0.29081	0.37206	0.78706	0.79490	0.78706	0.79490	0.76129
2	0.75748	0.81477	0.38250	0.63089	0.82169	0.32476	0.39515	0.81221	0.81477	0.81221	0.81477	0.72341
3	0.74955	0.82167	0.39067	0.60789	0.79724	0.33301	0.41080	0.82101	0.82167	0.82101	0.82167	0.71338
4	0.69749	0.80683	0.41635	0.52789	0.70410	0.36716	0.45602	0.81154	0.80683	0.81154	0.80683	0.65738
5	0.63975	0.77973	0.45912	0.45959	0.61366	0.41557	0.51884	0.78952	0.77973	0.78952	0.77973	0.59775
6	0.62021	0.76891	0.50284	0.44683	0.58834	0.44319	0.57107	0.78058	0.76891	0.78058	0.76891	0.57821
7	0.72032	0.74064	0.43313	0.58782	0.68732	0.32337	0.50485	0.73944	0.74094	0.73944	0.74094	0.71051
8	0.65542	0.67579	0.45798	0.53195	0.62132	0.33324	0.47569	0.67518	0.67518	0.67518	0.67518	0.64702
9	0.61049	0.64497	0.46427	0.48929	0.57634	0.33776	0.47964	0.64623	0.64623	0.64623	0.64623	0.59950
10	0.56329	0.62111	0.49364	0.44490	0.53108	0.39429	0.50491	0.62532	0.62111	0.62532	0.62111	0.54760
11	0.51361	0.59769	0.53685	0.40321	0.48748	0.47302	0.54163	0.60524	0.59769	0.60524	0.59769	0.49248
12	0.42345	0.52094	0.55604	0.33711	0.40763	0.55364	0.54635	0.53090	0.52094	0.53090	0.52094	0.40104
13	0.39828	0.42442	0.38662	0.31809	0.36799	0.34536	0.38253	0.42681	0.42442	0.42442	0.42442	0.39425
14	0.38372	0.42847	0.41710	0.30402	0.35706	0.3921	0.41039	0.43295	0.42847	0.43295	0.42847	0.37516
15	0.38372	0.42847	0.41710	0.30402	0.35706	0.39521	0.41039	0.43295	0.42847	0.43295	0.42847	0.37516

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR TRANSITIONAL CHANNEL CATEGORY - LOW FLOW YEAR

OBS	NAME	JA_TDEPC	FB_TDEPC	MA_TDEPC	AP_TDEPC	MY_TDEPC	JN_TDEPC	JL_TDEPC	AU_TDEPC	SP_TDEPC	OC_TDEPC	NO_TDEPC	DE_TDEPC
1	K06TDEPC	0.69008	0.89832	0.81487	0.89720	0.80531	0.52785	0.86805	0.91844	0.89832	0.91844	0.89832	0.63026
2	K08TDEPC	0.59456	0.82610	0.84967	0.90810	0.84817	0.59435	0.88833	0.88833	0.85523	0.82610	0.85523	0.53433
3	K10TDEPC	0.53829	0.76746	0.83244	0.87893	0.83759	0.59915	0.86339	0.86339	0.80284	0.76746	0.80284	0.48125
4	K12TDEPC	0.47869	0.68744	0.77477	0.80631	0.79459	0.58744	0.79515	0.79515	0.73140	0.68744	0.73140	0.42749
5	K14TDEPC	0.47520	0.69040	0.83497	0.95175	0.85433	0.67177	0.84684	0.84684	0.73187	0.69040	0.73187	0.42394
6	K16TDEPC	0.49702	0.65876	0.70180	0.73051	0.73751	0.56599	0.71847	0.71847	0.70453	0.65876	0.70453	0.45624
7	K20TDEPC	0.43232	0.61524	0.93171	0.89089	0.94538	0.95029	0.90610	0.90610	0.63324	0.61524	0.63324	0.39555
8	K24TDEPC	0.33179	0.51441	0.91467	0.85124	0.92055	0.97484	0.87615	0.87615	0.52430	0.51441	0.52430	0.29862
9	K28TDEPC	0.30039	0.47858	0.89347	0.82376	0.90114	0.97574	0.85066	0.85066	0.48827	0.47858	0.48827	0.26891
10	K32TDEPC	0.34241	0.51184	0.86189	0.80439	0.88220	0.94617	0.82440	0.82440	0.53120	0.51184	0.53120	0.31031
11	K36TDEPC	0.24187	0.39887	0.79129	0.71670	0.81124	0.13093	0.74272	0.74272	0.41455	0.39887	0.41455	0.21461
12	K40TDEPC	0.23884	0.36438	0.70758	0.64534	0.70534	0.73996	0.84846	0.84846	0.41028	0.38438	0.41028	0.21168
13	K46TDEPC	0.21689	0.34537	0.59791	0.54812	0.63846	0.73563	0.56115	0.56115	0.34537	0.34537	0.34537	0.19137
14	K50TDEPC	0.18102	0.32273	0.54218	0.49296	0.58499	0.68797	0.50532	0.50532	0.33683	0.30273	0.33683	0.15676
15	KGTDEPC	0.18102	0.30273	0.54218	0.49296	0.58499	0.68797	0.50532	0.50532	0.33683	0.30273	0.33683	0.15676

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL  
AND OPERATIONAL DEPTHS FOR TRANSITIONAL CHANNEL CATEGORY - LOW FLOW

OBS	JA_TDADJ	FB_TDADJ	MA_TDADJ	AP_TDADJ	NY_TDADJ	JN_TDADJ	JL_TDADJ	AU_TDADJ	SP_TDADJ	OC_TDADJ	NO_TDADJ	DE_TDADJ
1	0.45777	0.42387	0.29757	0.32097	0.28593	0.22956	0.31168	0.42224	0.42224	0.42224	0.42224	0.42224
2	0.46611	0.44004	0.32730	0.34838	0.31570	0.25852	0.34002	0.44067	0.44067	0.44067	0.44067	0.44067
3	0.48358	0.45804	0.34870	0.36693	0.33757	0.27886	0.36084	0.46053	0.45804	0.46053	0.45804	0.46053
4	0.50582	0.47585	0.36750	0.38594	0.36750	0.30122	0.37827	0.48127	0.47585	0.48127	0.47585	0.51131
5	0.52397	0.49495	0.39453	0.41081	0.38488	0.32938	0.40408	0.49985	0.49985	0.49985	0.49985	0.49985
6	0.61424	0.56107	0.42269	0.44330	0.41660	0.35642	0.43335	0.56831	0.56831	0.56107	0.56831	0.56831
7	0.60818	0.56539	0.49652	0.50149	0.48268	0.45937	0.49557	0.56353	0.56353	0.56353	0.56353	0.56353
8	0.57819	0.54200	0.50319	0.50200	0.48732	0.47559	0.50175	0.53775	0.54200	0.53775	0.54200	0.59612
9	0.58626	0.54952	0.51674	0.51356	0.50086	0.49410	0.51396	0.54522	0.54522	0.54522	0.54522	0.54522
10	0.63120	0.58602	0.52995	0.52993	0.51714	0.50761	0.52883	0.58504	0.58504	0.58504	0.58504	0.58504
11	0.61872	0.57453	0.5023	0.53421	0.52732	0.53364	0.53484	0.57267	0.57267	0.57267	0.57267	0.57267
12	0.57047	0.61959	0.56118	0.55794	0.55201	0.55668	0.55669	0.62216	0.61959	0.62216	0.61959	0.62216
13	0.52763	0.63947	0.55753	0.55205	0.55511	0.55448	0.55450	0.64560	0.63947	0.64560	0.63947	0.64560
14	0.49371	0.64224	0.55829	0.55767	0.55391	0.55996	0.55455	0.64964	0.64964	0.64964	0.64964	0.64964
15	0.49371	0.64224	0.55529	0.55767	0.55391	0.55996	0.55455	0.64964	0.64964	0.64964	0.64964	0.64964

GAVINS UNADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR WIDE CHANNEL CATEGORY - LOW FLOW YEAR

OBS	NAME	JA_WDEPC	FB_WDEPC	MA_WDEPC	AP_WDEPC	MY_WDEPC	JN_WDEPC	JL_WDEPC	AU_WDEPC	SP_WDEPC	OC_WDEPC	NO_WDEPC	DE_WDEPC
1	K06WDEPC	0.88839	0.75440	0.85209	0.77905	0.82503	0.52918	0.80294	0.75888	0.75410	0.75888	0.75410	0.90395
2	K08WDEPC	0.95629	0.85114	0.89570	0.74861	0.83326	0.58880	0.78902	0.85037	0.85114	0.85037	0.85114	0.96431
3	K10WDEPC	0.97998	0.92369	0.92096	0.72809	0.83751	0.65523	0.77912	0.91959	0.92369	0.91959	0.92369	0.97574
4	K12WDEPC	0.97708	0.94220	0.93643	0.74594	0.85517	0.68820	0.79715	0.93869	0.94220	0.93869	0.94220	0.96725
5	K14WDEPC	0.96517	0.96024	0.94104	0.74669	0.85672	0.72447	0.79443	0.95626	0.96024	0.95626	0.96024	0.94801
6	K16WDEPC	0.95662	0.96557	0.95883	0.77651	0.88500	0.75825	0.82712	0.96248	0.96457	0.96248	0.96457	0.93595
7	K20WDEPC	0.82124	0.83641	0.97464	0.95576	0.98968	0.84427	0.97616	0.84875	0.83641	0.84875	0.83641	0.79896
8	K24WDEPC	0.65235	0.65053	0.79803	0.91931	0.87507	0.62791	0.90251	0.62543	0.60503	0.62543	0.60503	0.64729
9	K28WDEPC	0.61609	0.54981	0.74173	0.88111	0.82603	0.54928	0.86138	0.57995	0.54981	0.57995	0.54981	0.61623
10	K32WDEPC	0.70854	0.66504	0.81822	0.91222	0.87885	0.60507	0.90074	0.66332	0.64504	0.66332	0.64504	0.70669
11	K36WDEPC	0.79293	0.69951	0.84190	0.87707	0.86982	0.56860	0.87726	0.71341	0.63951	0.71341	0.63951	0.79774
12	K40WDEPC	0.91092	0.84663	0.93823	0.87467	0.91860	0.66954	0.89782	0.85403	0.84663	0.85403	0.84663	0.90743
13	K46WDEPC	0.93404	0.90070	0.97048	0.87106	0.93468	0.73066	0.90323	0.90078	0.90070	0.90078	0.90070	0.92279
14	K50WDEPC	0.94635	0.94324	0.96419	0.79194	0.89234	0.75301	0.84025	0.94254	0.94324	0.94254	0.94324	0.92846
15	KGTWDEPC	0.94635	0.94324	0.96419	0.79194	0.89234	0.75301	0.84025	0.94254	0.94324	0.94254	0.94324	0.92846

GAVINS TOPWIDTH ADJUSTED CORRELATION COEFFICIENTS OF HISTORICAL AND  
OPERATIONAL DEPTHS FOR WIDE CHANNEL CATEGORY - LOW FLOW YEAR

OBS	JA_WDADJ	FB_WDADJ	MA_WDADJ	AP_WDADJ	MY_WDADJ	JN_WDADJ	JL_WDADJ	AU_WDADJ	SP_WDADJ	OC_WDADJ	NO_WDADJ	DE_WDADJ
1	0.77011	0.82153	0.55080	0.58742	0.52048	0.38759	0.56890	0.83182	0.82153	0.83182	0.82153	0.73104
2	0.78366	0.85161	0.57394	0.58778	0.53226	0.40979	0.57470	0.85957	0.85161	0.85957	0.85161	0.74085
3	0.75200	0.83907	0.61341	0.61267	0.56269	0.44985	0.60279	0.84567	0.83907	0.84567	0.83907	0.70550
4	0.74199	0.83710	0.62578	0.62643	0.57491	0.46497	0.61621	0.84375	0.83710	0.84375	0.83710	0.69512
5	0.70410	0.80659	0.65704	0.65419	0.60270	0.49751	0.64447	0.81282	0.80659	0.81282	0.80659	0.65713
6	0.68009	0.78421	0.68349	0.68822	0.63074	0.52288	0.67644	0.79103	0.78421	0.79103	0.78421	0.63335
7	0.71971	0.83343	0.60602	0.66777	0.58558	0.48240	0.64350	0.84723	0.83343	0.84723	0.83343	0.66333
8	0.54510	0.60808	0.66102	0.78341	0.66106	0.51008	0.74212	0.62183	0.60808	0.62183	0.60808	0.51164
9	0.46335	0.51031	0.73676	0.88486	0.74073	0.55855	0.83542	0.52222	0.51031	0.52222	0.51031	0.43629
10	0.45704	0.50538	0.82433	0.82433	0.94972	0.81687	0.62056	0.91433	0.51602	0.50538	0.50538	0.42985
11	0.41035	0.44670	0.86897	0.79762	0.91989	0.70843	0.83472	0.45476	0.44670	0.45476	0.44670	0.38739
12	0.42577	0.47252	0.89020	0.77550	0.91889	0.77454	0.82150	0.47905	0.47252	0.47905	0.47252	0.40014
13	0.41289	0.46600	0.86714	0.74162	0.88782	0.83796	0.78937	0.47182	0.46600	0.47182	0.46600	0.38648
14	0.40760	0.46735	0.84789	0.69671	0.85183	0.86528	0.74870	0.47174	0.46735	0.47174	0.46735	0.38023
15	0.40760	0.46735	0.84789	0.69671	0.85183	0.86528	0.74870	0.47174	0.46735	0.47174	0.46735	0.38023

# **Appendix B**

## **Gavins Point Canberra**

### **Coefficients**

---

Tables of coefficients of historical/operational depth-velocity percent frequencies are presented for four channel categories (divided, narrow, transitional, and wide) in a median year. Coefficients are unadjusted, adjusted, and adjusted and weighted by reach.

**Table B1**
**Gavins Point Canberra Coefficients of Historical/Operational Depth-Velocity  
Percent Frequencies Unadjusted for Divided Channel Category in a Median  
Year**

OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.22230	0.18001	0.20648	0.19410	0.21508	0.21428	0.17972	0.17770	0.17837	0.18001	0.22309	
2	0.25125	0.24568	0.21061	0.21661	0.24203	0.24203	0.22712	0.23147	0.23917	0.23609	0.24568	0.24530
3	0.28059	0.28035	0.25574	0.24138	0.25555	0.25555	0.26361	0.24980	0.26980	0.26292	0.28035	0.26148
4	0.25387	0.27904	0.27672	0.28194	0.29264	0.29264	0.29541	0.27976	0.27789	0.27916	0.27904	0.25114
5	0.26133	0.29340	0.32908	0.32810	0.33409	0.33409	0.33975	0.29026	0.29056	0.29049	0.29340	0.26478
6	0.33307	0.37245	0.39204	0.41350	0.44133	0.44133	0.44021	0.39297	0.37807	0.38280	0.37245	0.32916
7	0.42286	0.44586	0.48074	0.50149	0.56624	0.56624	0.53681	0.47065	0.44888	0.45513	0.44586	0.41912
8	0.37470	0.40292	0.42981	0.45008	0.52829	0.52829	0.47448	0.44396	0.41151	0.42195	0.40292	0.36276
9	0.38896	0.38523	0.49846	0.52675	0.54131	0.54131	0.53870	0.44950	0.40182	0.41742	0.38523	0.38421
10	0.39551	0.40710	0.48583	0.52132	0.50313	0.50313	0.51770	0.45570	0.42197	0.43254	0.40710	0.39298
11	0.36102	0.36249	0.48961	0.53649	0.53348	0.53348	0.53070	0.39267	0.37011	0.37765	0.36249	0.35937
12	0.42412	0.40670	0.53535	0.53897	0.53714	0.53714	0.53858	0.45672	0.41856	0.42953	0.40670	0.42876
13	0.39476	0.39426	0.46223	0.45297	0.46203	0.46203	0.46182	0.41553	0.40212	0.41026	0.39426	0.39003
14	0.35145	0.33037	0.41991	0.42080	0.43828	0.43828	0.42145	0.34237	0.33347	0.33632	0.33037	0.34636
OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.14001	0.10891	0.07684	0.07670	0.07202	0.07202	0.07697	0.10448	0.10664	0.10619	0.10891	0.14746
2	0.15825	0.14864	0.07838	0.08559	0.08105	0.08105	0.08158	0.13457	0.14353	0.14055	0.14864	0.16213
3	0.19873	0.19073	0.10702	0.10726	0.09623	0.09623	0.10647	0.16331	0.18207	0.17601	0.19073	0.19434
4	0.21690	0.22900	0.13969	0.15112	0.13294	0.13294	0.14394	0.22062	0.22622	0.22544	0.22900	0.22517
5	0.22327	0.24079	0.16612	0.17587	0.15177	0.15177	0.16554	0.22891	0.23654	0.23459	0.24079	0.23740
6	0.29983	0.32206	0.20852	0.23353	0.21123	0.21123	0.22599	0.32653	0.32428	0.32571	0.32206	0.31096
7	0.40305	0.44338	0.29735	0.32936	0.31517	0.31517	0.32047	0.45478	0.44773	0.45034	0.44338	0.37781
8	0.33006	0.37270	0.28421	0.31601	0.31435	0.31435	0.30283	0.42930	0.38421	0.39755	0.37270	0.29948
9	0.32361	0.33824	0.34400	0.38600	0.33617	0.33617	0.35883	0.41438	0.35645	0.37400	0.33824	0.29747
10	0.28193	0.31085	0.36949	0.42098	0.34433	0.34433	0.38002	0.36998	0.32642	0.33883	0.31085	0.25513
11	0.23713	0.25729	0.38856	0.45208	0.38098	0.38998	0.40651	0.29850	0.26656	0.27584	0.25729	0.21219
12	0.25309	0.26520	0.44387	0.47449	0.40076	0.40076	0.43100	0.32187	0.27748	0.28935	0.26520	0.22613
13	0.23557	0.25709	0.38324	0.39878	0.34472	0.34472	0.36957	0.29284	0.26659	0.27636	0.25709	0.20570
14	0.20972	0.21542	0.34816	0.37046	0.32700	0.32700	0.33727	0.24128	0.22108	0.22656	0.21542	0.18267
OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.019602	0.015247	0.010758	0.010738	0.010083	0.010083	0.010775	0.014628	0.014930	0.014867	0.015247	0.020644
2	0.022155	0.020809	0.010973	0.011983	0.011347	0.011347	0.011421	0.018840	0.020094	0.019677	0.020809	0.022699
3	0.027822	0.026702	0.014983	0.015016	0.013472	0.013472	0.014906	0.022863	0.025490	0.024641	0.026702	0.027208
4	0.030367	0.032060	0.019557	0.021157	0.018611	0.018611	0.020151	0.030887	0.031671	0.031562	0.032060	0.031524
5	0.031258	0.033710	0.023257	0.024621	0.021247	0.021247	0.023176	0.032047	0.033115	0.032842	0.033710	0.033236
6	0.041976	0.045089	0.029193	0.032694	0.029573	0.029573	0.031639	0.045714	0.045399	0.045600	0.045089	0.043534
7	0.056427	0.062073	0.041629	0.046110	0.044123	0.044123	0.044866	0.063669	0.062683	0.063047	0.062073	0.052893
8	0.046208	0.052178	0.039790	0.044242	0.044009	0.044009	0.042396	0.060102	0.053789	0.055657	0.052178	0.041927
9	0.045305	0.047354	0.048161	0.054040	0.047063	0.047063	0.050237	0.058013	0.049903	0.052360	0.047354	0.041646
10	0.039471	0.043519	0.051729	0.058938	0.048206	0.048206	0.053203	0.051797	0.045699	0.047436	0.043519	0.035718
11	0.033198	0.036020	0.054399	0.063292	0.053338	0.053338	0.056911	0.041791	0.037318	0.038618	0.036020	0.029707
12	0.035433	0.037128	0.062141	0.066429	0.056106	0.056106	0.060340	0.045061	0.038848	0.040509	0.037128	0.031658
13	0.032980	0.035992	0.053654	0.055829	0.048260	0.048260	0.051740	0.040998	0.037322	0.038691	0.035992	0.028798
14	0.029361	0.030159	0.048742	0.051865	0.045780	0.045780	0.047217	0.033780	0.030951	0.031718	0.030159	0.025574

(Sheet 1 of 4)

**Table B1 (Continued)**

OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.18558	0.14054	0.06363	0.08645	0.09977	0.09977	0.08823	0.16464	0.14252	0.14864	0.14054	0.18549
2	0.19426	0.17364	0.09133	0.10615	0.10195	0.10195	0.09411	0.19457	0.17675	0.18301	0.17364	0.18111
3	0.21036	0.18539	0.12526	0.14123	0.11968	0.11968	0.12376	0.21386	0.19049	0.19889	0.18539	0.22062
4	0.23696	0.22222	0.11044	0.14077	0.11750	0.11750	0.12211	0.21671	0.21470	0.21324	0.22222	0.27154
5	0.24845	0.25807	0.13571	0.14274	0.11944	0.11944	0.12588	0.23857	0.24215	0.23817	0.25807	0.23825
6	0.31745	0.25365	0.16136	0.15799	0.12571	0.12571	0.14636	0.24392	0.24420	0.24545	0.25365	0.25959
7	0.35940	0.36779	0.31509	0.34893	0.29469	0.29469	0.34671	0.34999	0.36308	0.42050	0.40354	0.39321
8	0.36277	0.37615	0.38303	0.34841	0.35739	0.35739	0.37947	0.35734	0.37842	0.38024	0.37615	0.40246
9	0.35475	0.33610	0.37369	0.36946	0.28991	0.28991	0.30678	0.27409	0.28547	0.28445	0.28903	0.37709
10	0.30093	0.34983	0.43112	0.41334	0.45242	0.45242	0.46374	0.34510	0.34438	0.34368	0.34983	0.31112
11	0.30237	0.34310	0.50178	0.50610	0.46500	0.46500	0.57392	0.33952	0.34158	0.34095	0.34310	0.30790
12	0.27554	0.30665	0.38678	0.46574	0.53838	0.53838	0.44840	0.36503	0.31871	0.33176	0.30665	0.29981
13	0.21315	0.29841	0.44263	0.50622	0.54799	0.54799	0.51185	0.32425	0.30913	0.31440	0.29841	0.21797
14	0.22086	0.29789	0.45360	0.49516	0.45040	0.45040	0.45480	0.31625	0.29783	0.30613	0.29789	0.21005

OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.11012	0.08281	0.03415	0.04640	0.05111	0.05111	0.04661	0.09670	0.08392	0.08747	0.08281	0.11056
2	0.11527	0.10231	0.04902	0.05697	0.05223	0.05223	0.04972	0.11428	0.10407	0.10769	0.10231	0.10795
3	0.12482	0.10923	0.06723	0.07579	0.06131	0.06131	0.06538	0.12561	0.11217	0.11704	0.10923	0.13151
4	0.14287	0.13303	0.06022	0.07676	0.06116	0.06116	0.06555	0.12932	0.12845	0.12750	0.13303	0.16445
5	0.14979	0.15449	0.07400	0.07783	0.06217	0.06217	0.06757	0.14237	0.14487	0.14240	0.15449	0.14429
6	0.19139	0.15184	0.08799	0.08615	0.06544	0.06544	0.07856	0.14556	0.14610	0.14675	0.15184	0.15722
7	0.27679	0.28646	0.27970	0.30974	0.27647	0.27647	0.31379	0.27392	0.28307	0.32815	0.31431	0.30065
8	0.24524	0.25781	0.30739	0.27962	0.30624	0.30624	0.31163	0.24638	0.25967	0.26124	0.25781	0.26966
9	0.21761	0.20948	0.27874	0.27559	0.23276	0.23276	0.23484	0.17200	0.17816	0.17777	0.18014	0.22895
10	0.17164	0.20307	0.30479	0.29222	0.34640	0.34640	0.33721	0.20185	0.20021	0.20011	0.20307	0.17544
11	0.16837	0.19456	0.34861	0.35161	0.35061	0.35061	0.41043	0.19404	0.19400	0.19394	0.19456	0.16944
12	0.13839	0.15727	0.24962	0.30058	0.38057	0.38057	0.29887	0.18890	0.16375	0.17076	0.15727	0.14855
13	0.05059	0.07456	0.17962	0.20543	0.26203	0.26203	0.22044	0.08278	0.07757	0.07923	0.07456	0.05000
14	0.05242	0.07443	0.18407	0.20094	0.21536	0.21536	0.19587	0.08073	0.07474	0.07715	0.07443	0.04818

OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.034138	0.025670	0.01059	0.01438	0.01584	0.01584	0.01445	0.029977	0.026016	0.02712	0.025670	0.034274
2	0.035734	0.031715	0.01519	0.01766	0.01619	0.01619	0.01541	0.035427	0.032263	0.03339	0.031715	0.033466
3	0.038696	0.033862	0.02084	0.02350	0.01901	0.01901	0.02027	0.038939	0.034772	0.03628	0.033862	0.040767
4	0.044289	0.041239	0.01867	0.02380	0.01896	0.01896	0.02032	0.040090	0.039819	0.03952	0.041239	0.050980
5	0.046436	0.047891	0.02294	0.02413	0.01927	0.01927	0.02095	0.044136	0.044910	0.04414	0.047891	0.044730
6	0.059331	0.047071	0.02728	0.02671	0.02029	0.02029	0.02435	0.045125	0.045290	0.04549	0.047071	0.048737
7	0.085805	0.088803	0.08671	0.09602	0.08570	0.08570	0.09727	0.084915	0.087752	0.10173	0.097435	0.093201
8	0.076023	0.079923	0.09529	0.08668	0.09494	0.09494	0.09660	0.076376	0.080499	0.08098	0.079923	0.083595
9	0.067460	0.064938	0.08641	0.08543	0.07215	0.07215	0.07280	0.053319	0.055230	0.05511	0.055843	0.070975
10	0.053207	0.062953	0.09448	0.09059	0.10738	0.10738	0.10453	0.062573	0.062066	0.06203	0.062953	0.054387
11	0.052195	0.060313	0.10807	0.10900	0.10869	0.10869	0.12723	0.060152	0.060141	0.06012	0.060313	0.052528
12	0.042901	0.048754	0.07738	0.09318	0.11798	0.11798	0.09265	0.058559	0.050763	0.05294	0.048754	0.046051
13	0.015684	0.023113	0.05568	0.06368	0.08123	0.08123	0.06834	0.025660	0.024047	0.02456	0.023113	0.015501
14	0.016251	0.023072	0.05706	0.06229	0.06676	0.06676	0.06072	0.025028	0.023168	0.02392	0.023072	0.014937

(Sheet 2 of 4)

**Table B1 (Continued)**

OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.28083	0.31653	0.21726	0.22973	0.22973	0.19026	0.22889	0.32386	0.31148	0.31466	0.31653	0.29985
2	0.31725	0.34124	0.25468	0.26906	0.26906	0.22331	0.26278	0.34600	0.33645	0.33877	0.34124	0.34192
3	0.26979	0.32990	0.27223	0.28206	0.28206	0.23652	0.28167	0.33450	0.32387	0.32295	0.32990	0.30922
4	0.28956	0.36119	0.30760	0.30281	0.30281	0.26968	0.31662	0.36502	0.35217	0.35140	0.36119	0.32253
5	0.33743	0.37199	0.30846	0.32380	0.32380	0.27871	0.31195	0.38609	0.36591	0.36842	0.37199	0.35469
6	0.30070	0.33868	0.28522	0.28533	0.28533	0.25286	0.29468	0.34368	0.33161	0.33182	0.33868	0.32312
7	0.23785	0.23311	0.21433	0.21847	0.21847	0.24505	0.23990	0.22459	0.22937	0.22704	0.23311	0.22950
8	0.20900	0.21294	0.21942	0.23822	0.23822	0.21510	0.23184	0.21443	0.20978	0.20992	0.21294	0.21071
9	0.24670	0.21968	0.23240	0.24114	0.24114	0.20271	0.23961	0.22748	0.21817	0.21807	0.21968	0.24815
10	0.30093	0.21171	0.25501	0.25911	0.25911	0.23851	0.26012	0.21416	0.21002	0.21056	0.21171	0.26174
11	0.25419	0.22459	0.24681	0.25477	0.25477	0.23189	0.26500	0.22802	0.22281	0.22266	0.22459	0.25279
12	0.21342	0.22423	0.23417	0.24118	0.24118	0.20023	0.23039	0.21739	0.22043	0.21798	0.22423	0.20614
13	0.22850	0.21980	0.22883	0.23857	0.23857	0.21094	0.23741	0.22897	0.22164	0.22364	0.21980	0.21687
14	0.19302	0.18765	0.20697	0.22689	0.22689	0.18776	0.20543	0.21347	0.18933	0.19329	0.18765	0.18375
OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.13953	0.12353	0.06644	0.07025	0.05788	0.05788	0.06999	0.11888	0.12004	0.11977	0.12353	0.15148
2	0.17020	0.14380	0.08409	0.08884	0.07336	0.07336	0.08676	0.13714	0.14001	0.13924	0.14380	0.18651
3	0.15559	0.14944	0.09662	0.10011	0.08352	0.08352	0.09997	0.14251	0.14488	0.14268	0.14944	0.18131
4	0.18180	0.17812	0.11886	0.11701	0.10367	0.10367	0.12234	0.16931	0.17151	0.16902	0.17812	0.20588
5	0.21988	0.19040	0.12371	0.12986	0.11120	0.11120	0.12510	0.18586	0.18495	0.18392	0.19040	0.23499
6	0.22645	0.20034	0.13219	0.13225	0.11659	0.11659	0.13657	0.19120	0.19371	0.19143	0.20034	0.24741
7	0.18536	0.14270	0.10280	0.10479	0.11693	0.11693	0.11506	0.12930	0.13865	0.13555	0.14270	0.18185
8	0.16653	0.13327	0.10761	0.11683	0.10494	0.10494	0.11369	0.12623	0.12966	0.12814	0.13327	0.17071
9	0.20407	0.14273	0.11831	0.12276	0.10267	0.10267	0.12198	0.13901	0.13998	0.13819	0.14273	0.20870
10	0.25970	0.14351	0.13544	0.13763	0.12603	0.12603	0.13815	0.13654	0.14059	0.13921	0.14351	0.22967
11	0.23236	0.16126	0.13886	0.14334	0.12979	0.12979	0.14909	0.15399	0.15799	0.15593	0.16126	0.23495
12	0.21266	0.17550	0.14361	0.14791	0.12216	0.12216	0.14128	0.16003	0.17038	0.16639	0.17550	0.20344
13	0.21526	0.18265	0.14900	0.15534	0.13664	0.13664	0.15458	0.17896	0.18189	0.18126	0.18265	0.20045
14	0.17418	0.16178	0.13981	0.15327	0.12618	0.12618	0.13877	0.17310	0.16120	0.16253	0.16178	0.16243
OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.030697	0.027176	0.014616	0.015455	0.012734	0.012734	0.015398	0.026153	0.026410	0.026349	0.027176	0.033325
2	0.037445	0.031636	0.018501	0.019545	0.016138	0.016138	0.019088	0.030170	0.030803	0.030632	0.031636	0.041033
3	0.034229	0.032877	0.021257	0.022025	0.018374	0.018374	0.021993	0.031353	0.031873	0.031389	0.032877	0.039889
4	0.039995	0.039186	0.026149	0.025741	0.022807	0.022807	0.026914	0.037247	0.037732	0.037184	0.039186	0.045295
5	0.048373	0.041887	0.027216	0.028569	0.024464	0.024464	0.027522	0.040890	0.040689	0.040461	0.041887	0.051699
6	0.049820	0.044074	0.029082	0.029095	0.025651	0.025651	0.030046	0.042065	0.042616	0.042115	0.044074	0.054430
7	0.040780	0.031393	0.022616	0.023053	0.025725	0.025725	0.025313	0.028447	0.030504	0.029821	0.031393	0.040007
8	0.036637	0.029320	0.023673	0.025702	0.023087	0.023087	0.025012	0.027770	0.028525	0.028191	0.029320	0.037556
9	0.044895	0.031401	0.026028	0.027008	0.022586	0.022586	0.026835	0.030582	0.030796	0.030401	0.031401	0.045914
10	0.057134	0.031572	0.029797	0.030278	0.027727	0.027727	0.030394	0.030038	0.030930	0.030627	0.031572	0.050526
11	0.051120	0.035478	0.030549	0.031534	0.028554	0.028554	0.032799	0.033878	0.034757	0.034305	0.035478	0.051689
12	0.046785	0.038609	0.031593	0.032540	0.026876	0.026876	0.031082	0.035206	0.037483	0.036607	0.038609	0.044756
13	0.047356	0.040183	0.032780	0.034175	0.030061	0.030061	0.034007	0.039372	0.040015	0.039877	0.040183	0.044100
14	0.038319	0.035592	0.030759	0.033720	0.027760	0.027760	0.030529	0.038082	0.035464	0.035757	0.035592	0.035735

(Sheet 3 of 4)

**Table B1 (Concluded)**

OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.29929	0.31224	0.36315	0.36918	0.35833	0.35833	0.39465	0.30581	0.30941	0.30794	0.31224	0.29031
2	0.31180	0.40083	0.43304	0.44126	0.40143	0.40143	0.46186	0.37828	0.39258	0.38834	0.40083	0.30587
3	0.30568	0.37020	0.48268	0.48770	0.48129	0.48129	0.51708	0.36007	0.37520	0.37608	0.37020	0.28165
4	0.33732	0.42884	0.54054	0.52578	0.47669	0.47699	0.55865	0.41393	0.43496	0.43311	0.42884	0.31737
5	0.31716	0.39683	0.50729	0.50925	0.52474	0.52474	0.51517	0.40613	0.40589	0.41044	0.39683	0.29028
6	0.33499	0.42813	0.56063	0.57068	0.56094	0.56094	0.54044	0.44840	0.44071	0.44593	0.42813	0.31702
7	0.25627	0.32509	0.49964	0.50413	0.50488	0.50488	0.49435	0.33682	0.33329	0.33897	0.32509	0.25156
8	0.25612	0.30868	0.48575	0.49020	0.50056	0.50056	0.47612	0.32578	0.31712	0.32389	0.30868	0.24148
9	0.26723	0.31739	0.48431	0.49218	0.46559	0.46559	0.47989	0.33612	0.32421	0.32803	0.31739	0.25878
10	0.26097	0.30627	0.47325	0.48872	0.44519	0.44519	0.46274	0.32873	0.31183	0.31688	0.30627	0.26553
11	0.26740	0.31854	0.51388	0.53064	0.46043	0.46043	0.49578	0.34026	0.32850	0.33351	0.31854	0.26715
12	0.28862	0.30875	0.53042	0.52948	0.45574	0.45574	0.51920	0.32469	0.31471	0.31974	0.30875	0.29632
13	0.29307	0.31111	0.51718	0.50481	0.52668	0.52148	0.52148	0.33130	0.31877	0.32508	0.31111	0.29442
14	0.30515	0.31011	0.47760	0.47630	0.50447	0.50447	0.49167	0.32528	0.31295	0.31507	0.31011	0.29757
OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.22864	0.19575	0.13058	0.13377	0.12295	0.12295	0.13993	0.17247	0.18974	0.18480	0.19575	0.22293
2	0.24256	0.25590	0.15856	0.16282	0.14026	0.14026	0.16676	0.21724	0.24515	0.23732	0.25590	0.23918
3	0.25081	0.24927	0.18641	0.18980	0.17736	0.17736	0.19691	0.21809	0.24712	0.24240	0.24927	0.23229
4	0.28003	0.29216	0.21121	0.20703	0.17773	0.17773	0.21524	0.25367	0.28985	0.28245	0.29216	0.26483
5	0.27585	0.28325	0.20768	0.21009	0.20498	0.20498	0.20796	0.26076	0.28338	0.28043	0.28325	0.25378
6	0.30027	0.31493	0.23654	0.24263	0.22582	0.22582	0.22483	0.29671	0.31710	0.31400	0.31493	0.28563
7	0.20941	0.31558	0.27818	0.28285	0.26822	0.26822	0.27139	0.29411	0.31646	0.31498	0.31558	0.20402
8	0.14933	0.25842	0.32397	0.32946	0.31855	0.31855	0.31311	0.31079	0.27354	0.28726	0.25842	0.13903
9	0.09873	0.21008	0.37170	0.38066	0.34097	0.34097	0.36316	0.26765	0.22407	0.23588	0.21008	0.09343
10	0.06598	0.17339	0.38920	0.40502	0.34935	0.34935	0.37523	0.23346	0.18631	0.19883	0.17339	0.06473
11	0.01128	0.10323	0.49396	0.51400	0.42231	0.42231	0.46990	0.16756	0.11849	0.13198	0.10323	0.01409
12	0.02821	0.08598	0.52373	0.52683	0.42938	0.42938	0.50549	0.14657	0.09948	0.11258	0.08598	0.03218
13	0.05550	0.06324	0.50140	0.48539	0.51789	0.51789	0.51307	0.12715	0.07731	0.09106	0.06324	0.05908
14	0.07083	0.05216	0.45341	0.44832	0.50319	0.50319	0.47399	0.11457	0.06516	0.07767	0.05216	0.07251
OBS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.075451	0.06460	0.04309	0.04414	0.04057	0.04057	0.04618	0.05691	0.06261	0.06098	0.06460	0.073567
2	0.080046	0.08445	0.05233	0.05373	0.04629	0.04629	0.05503	0.07169	0.08090	0.07832	0.08445	0.078929
3	0.082767	0.08226	0.06152	0.06263	0.05853	0.05853	0.06498	0.07197	0.08155	0.07999	0.08226	0.076656
4	0.092408	0.09641	0.06970	0.06832	0.05865	0.05865	0.07103	0.08371	0.09565	0.09321	0.09641	0.087393
5	0.091030	0.09347	0.06853	0.06933	0.06764	0.06764	0.06863	0.08605	0.09352	0.09254	0.09347	0.083746
6	0.099089	0.10393	0.07806	0.08007	0.07452	0.07452	0.07419	0.09791	0.10464	0.10362	0.10393	0.094257
7	0.069106	0.10414	0.09180	0.09334	0.08851	0.08851	0.08956	0.09706	0.10443	0.10394	0.10414	0.067327
8	0.049280	0.08528	0.10691	0.10872	0.10512	0.10512	0.10333	0.10256	0.09027	0.09479	0.08528	0.045879
9	0.032581	0.06933	0.12266	0.12562	0.11252	0.11252	0.11984	0.08833	0.07394	0.07784	0.06933	0.030830
10	0.021772	0.05722	0.12844	0.13366	0.11529	0.11529	0.12383	0.07704	0.06148	0.06561	0.05722	0.021361
11	0.003721	0.03407	0.16301	0.16962	0.13936	0.13936	0.15507	0.05529	0.03910	0.04355	0.03407	0.004649
12	0.009309	0.02837	0.17283	0.17386	0.14170	0.14170	0.16681	0.04837	0.03283	0.03715	0.02837	0.010618
13	0.018314	0.02087	0.16546	0.16018	0.17090	0.17090	0.16931	0.04196	0.02551	0.03005	0.02087	0.019498
14	0.023374	0.01721	0.14963	0.14795	0.16605	0.16605	0.15642	0.03781	0.02150	0.02563	0.01721	0.023928

(Sheet 4 of 4)

# REPORT DOCUMENTATION PAGE

*Form Approved  
OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

<b>1. AGENCY USE ONLY (Leave blank)</b>			<b>2. REPORT DATE</b> May 1995		<b>3. REPORT TYPE AND DATES COVERED</b> Final report	
<b>4. TITLE AND SUBTITLE</b> Physical Habitat Analysis Using the Riverine Community Habitat Assessment and Restoration Concept (RCHARC): Missouri River Case History					<b>5. FUNDING NUMBERS</b> Work Unit 32698	
<b>6. AUTHOR(S)</b> John M. Nestler, L. Toni Schneider, Douglas C. Latka, Peter N. Johnson						
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> See reverse.					<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b> Technical Report EL-95-18	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> U.S. Army Corps of Engineers, Washington, DC 20314-1000; U.S. Army Engineer Division, Missouri River P.O. Box 103 Downtown Station, Omaha, NE 68101-0103					<b>10. SPONSORING/MONITORING AGENCY REPORT NUMBER</b>	
<b>11. SUPPLEMENTARY NOTES</b> Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.						
<b>12a. DISTRIBUTION/AVAILABILITY STATEMENT</b> Approved for public release; distribution is unlimited.				<b>12b. DISTRIBUTION CODE</b>		
<b>13. ABSTRACT (Maximum 200 words)</b> Increased water resources demand in rivers regulated by U.S. Army Corps of Engineers dams has intensified the conflict between preservation of lotic ecosystems and economic benefits of stream regulation or channel modification. The Riverine Community Habitat and Restoration Concept (RCHARC) facilitates evaluation of effects of different channel configurations or release patterns on fish habitat and can be used to balance water resources development and natural resource preservation. The RCHARC is applied to the Gavins Point Dam tailwater of the Missouri River as a case history to assess the effects of different reservoir release alternatives on habitat for native riverine warmwater fishes.  Application of the RCHARC requires four steps. First a comparison standard must be selected against which the project alternatives can be contrasted. Second, hydrologic and hydraulic features of the comparison standard having fish habitat significance are described and summarized as an annual series of monthly depth or velocity frequency distributions. Third, a similar approach is used to describe hydrologic and hydraulic features of the project alternatives. Fourth, the habitat value of each of the project alternatives is determined by similarity of their depth or velocity distributions to the distributions of the standard. The more similar an alternative is to the standard system, the higher it will be ranked.						
<b>14. SUBJECT TERMS</b> Gavins Point Missouri River Physical habitat assessment/restoration			<b>RCHARC</b> Reservoir release alternatives Riverine fisheries		<b>Tailwater habitat</b> Warmwater fish	
					<b>15. NUMBER OF PAGES</b> 106	
					<b>16. PRICE CODE</b>	
<b>17. SECURITY CLASSIFICATION OF REPORT</b> UNCLASSIFIED		<b>18. SECURITY CLASSIFICATION OF THIS PAGE</b> UNCLASSIFIED		<b>19. SECURITY CLASSIFICATION OF ABSTRACT</b>		<b>20. LIMITATION OF ABSTRACT</b>

**7. (Concluded).**

U.S. Army Engineer Waterways Experiment Station  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199

U.S. Army Engineer Division, Missouri River  
12565 West Center Road  
Omaha, NE 68101-0103

ASCI Corporation, Inc.  
Trotter Shoals Laboratory  
Highway 72 West, P.O. Box 533  
Calhoun Falls, SC 29628